

Exhibit 27

Health Sciences

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**Evaluation of the Scientific
Literature on the Health
Effects Associated with Wind
Turbines and Low Frequency
Sound**

Oct 2009



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Literature on the Health Effects
Associated with Wind Turbines
and Low Frequency Sound**

Prepared for

Wisconsin Public Service Commission
Docket No. 6630-CE-302

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October 20, 2009

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Executive Summary

This white paper presents a review of the human health effects associated with infrasound and low frequency sound, preceded by an introduction to the basic concepts of epidemiology, causation, the peer review process, the science of public health, and the precautionary principle.

The goal of this white paper was to highlight key points regarding the health concerns of those involved with the positioning of wind turbines, rather than an in-depth review of the science of sound. The research involving sound is massive in its depth and breadth and is expanding daily. Research on health effects associated with human exposure to sound has evolved from the study of physical damage to the study of psychological and other effects, from ringing in the ears to non-specific physical symptoms. Early research in low frequency noise exposures is difficult to evaluate due to the diversity of the exposure and non-specific nature of the reported health effects. As of this review, there has not been a specific health condition documented in the peer reviewed published literature to be classified as a disease caused by exposure to sound levels and frequencies generated by the operation of wind turbines. That does not mean that there cannot be an effect. Numerous scientific papers document physiological responses to low frequency sound, but the majority of these effects are consistent with human response to environmental stimuli of varied nature and at higher decibel levels than produced by wind turbines. One of the most prominent non-physiological effects noted across the gamut of scientific as well as lay press literature is the annoying qualities of sound as was so vividly pointed out in one of the discussions when it was said that “one man’s music is another man’s unbearable noise.” Annoyance is a normal response and is not predictable based on the sound level below the painful level. It is clear that some people respond negatively to the noise qualities generated by the operation of wind turbines, but there is no peer-reviewed, scientific data to support a claim that wind turbines are causing disease or specific health conditions. Annoyance regarding the wind turbines is an elusive factor that could underlie a majority of the health complaints being attributed to wind turbine operations.

Overview of Epidemiology

Epidemiology is the study of the distribution and determinants of health events in populations (Last JM. 2001). The key elements of epidemiology are comparisons of health outcomes and exposures between populations (which allows for the calculation of relative risk estimates) and the careful evaluation of underlying determinants that may affect the outcome of comparisons of the study populations (bias and confounding). The study of health claims related to wind turbines is an excellent example of the potential influence of both bias (voluntary and involuntary exposures) and confounding (health outcome potentially related to direct and indirect exposure).

The scientific body of knowledge relative to a particular disease often starts with observations by clinicians (case reports and case series). These reports are not analytical studies because they have no comparison group or other means to test for associations. Case reports and reports of series of cases help generate scientific hypotheses; however, they cannot be used in testing for association or causation (Checkoway H. 2004). Surveys of only those persons claiming an effect give only one part of the total equation needed to assess the magnitude of risk associated with living near wind turbines. A collection of observations, no matter how well documented, are not sufficient to prove an increased risk, but instead are a first step in the scientific process. One must rely upon peer reviewed, published studies that are designed to reduce bias and confounding as much as possible.

The two most common types of analytical epidemiologic studies used to evaluate potential disease causation are cohort studies and case-control studies. In cohort studies, the researcher identifies two groups of individuals: individuals who have been exposed to a substance considered a possible cause of disease ("exposed" group) and individuals who have not been exposed ("unexposed" or "comparison" group). The researcher then follows both groups for a length of time and compares the rate of disease among the exposed individuals with the rate of disease among the unexposed individuals. The researchers determine whether there is an association between the exposure and the disease by calculating a relative risk (RR), which

divides the rate of disease among the exposed by the rate of disease among the unexposed, with a value statistically greater than 1.0 indicating a positive association. One type of cohort study is a standardized mortality (incidence) ratio study (SMR/SIR). In SMR/SIR studies of occupational groups, the number of observed cases for a particular occupational group is compared to the number one would expect for that group based on rates in the general population. These studies divide the observed number of cases by the expected number of cases, with a value statistically greater than 1.0 indicating a positive association.

In case-control studies, the researcher begins with a group of individuals who have the disease (cases) and then selects a group of individuals who do not have the disease (controls). The researcher then compares the case and control groups looking for differences in past exposures. An association is measured by dividing the odds of exposure among the diseased by the odds of exposure among the non-diseased, with a value statistically greater than 1.0 indicating a positive association.

Another type of epidemiologic study is a proportionate mortality (incidence) ratio study (PMR/PIR). PMR/PIR studies compare the proportions of selected causes of death or disease incidence in the exposed study group to the proportion in the unexposed study population, with a value statistically greater than 1.0 indicating a positive association.

No matter the study design, the researcher applying epidemiological principles and the reader of the studies must have a clear understanding of what constitutes the “disease” being studied. The description of the disease has to be sufficiently specific and described such that the comparisons are truly comparing “like to like.” In the case of health complaints related to wind turbines, there is a lack of specificity as to the health complaints. A disease or group of symptoms classified as “Wind Turbine Syndrome” has not been adopted by the medical community. The underlying complaint of annoyance is in and of itself not a disease or a specific manifestation of a specific exposure but instead a universal human response to a condition or situation that is not positively appreciated by the human receptor. Annoyances are highly variable in type (noise, smell, temperature, taste, vision) and vary from person to person. One can be annoyed by the action of others, as well as their own individual actions. Thus, “annoyance” is not a disease but

a universal human response that is highly non-specific. In conclusion, it has been found that there is a lack of epidemiologic research studies showing an association between health effects and exposure to noise at low frequency in combination with low sound pressure (dBA) generated by wind turbines.

Epidemiology, Association, and Causation

Historically, there have been careful clinical observations (case reports and series) that have stimulated a number of now-classic epidemiology research efforts that have identified important associations and ultimately the determinants of causal relationships. There have also been case reports identifying associations that did not hold up under epidemiological scrutiny, for example, those associating blunt force trauma and cancer. For this reason, case studies cannot be used to determine causation. A causal association can only be established by the evaluation of well designed and executed epidemiologic studies.

A landmark discussion of the process of moving from a disease being associated with a risk factor to a point where the scientific community is comfortable attributing causation to a risk factor was put forth by Sir Austin Bradford Hill in 1965. It was during this time that a number of papers, including the Surgeon General Report issued in 1964, began to more formally delineate the scientific reasoning process that justifies a conclusion that observed associations between an exposure and a disease are the result of a causal relationship between the exposure and the disease. Key statements from scientists during that time include the following:

“Disregarding then any such problem in semantics we have this situation. Our observations reveal *an association between two variables, perfectly clear-cut* and beyond what we would care to attribute to chance. What aspects of that association should we especially consider before deciding that the most likely interpretation of it is causation?” [italics added] (Hill AB. 1965). Hill’s nine criteria for causation have been described in a number of ways. They are commonly referred to as strength, consistency, specificity, temporality, biological gradient, plausibility, coherence, experiment, and analogy (Hill AB. 1965).

“If it be shown that an association exists, then the question is asked, ‘Does the association have a causal significance?’ ... To judge or evaluate the causal significance of the association between the attribute or agent and the disease, or effect on health, a number of criteria must be utilized...” [italics added] (Bayne-Jones S et al. 1964).

Finally, it should be noted that greater weight can be provided to the strength of an association when several epidemiologic studies performed by different researchers arrive at the same conclusions. And as a final step, researchers often submit their work for publication which then typically undergoes a peer review process for completeness and scientific soundness.

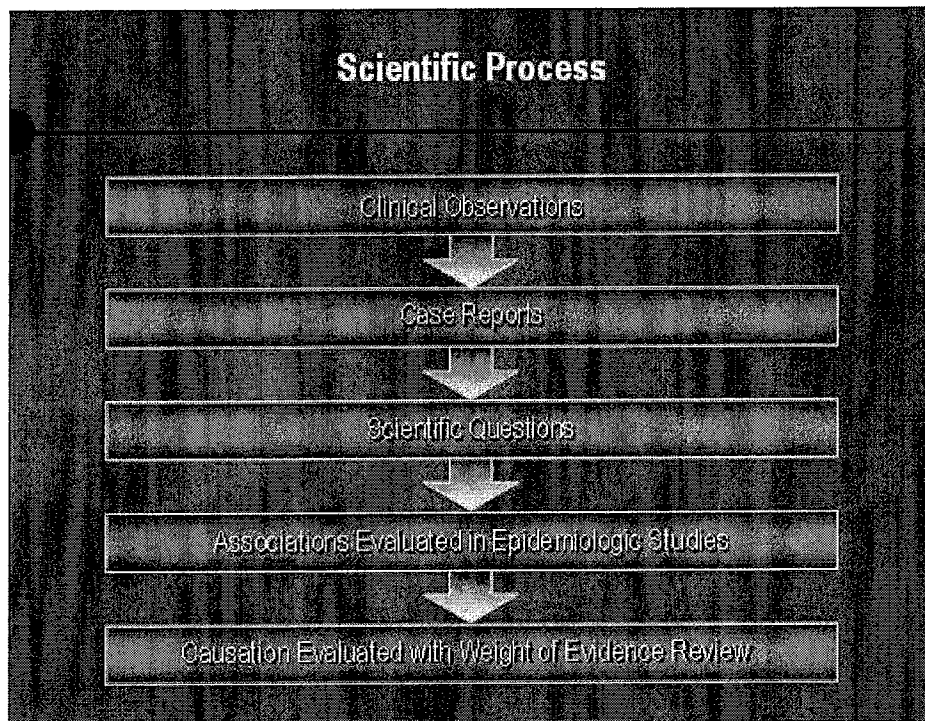


Figure 1. The Scientific Process

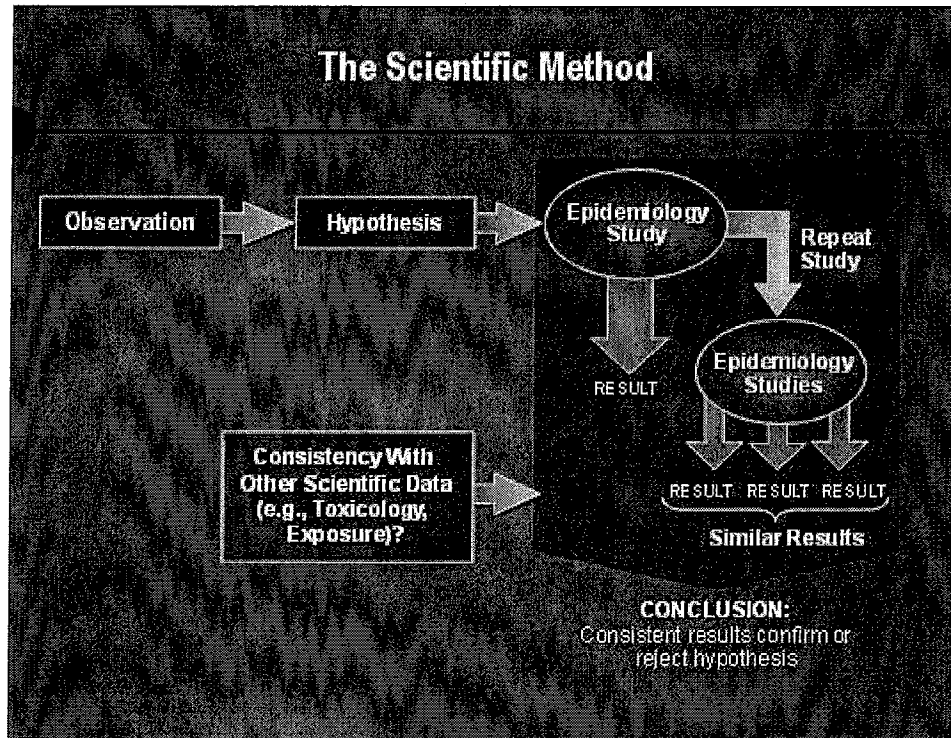


Figure 2. The Scientific Method

Peer Review Process

According to the Centers of Disease Control and Prevention (CDC), the peer review process is an “independent assessment of the scientific merit of research by panels of experts who provide written assurance that their reviews are free of real or perceived conflicts of interest. Results of the peer review process should therefore be without inherent bias and can be viewed as fair and just...” (CDC 2009).

Publication in a peer-reviewed journal remains the standard means of disseminating scientific results and has been since 1665, when the first recorded peer review process was performed at The Royal Society by the founding editor, Henry Oldenburg (UK Parliament and House of Commons 2004). Consequently, publications that have not undergone a peer review are likely to be regarded with skepticism and doubt by scholars and professionals.

Generally, the peer review process uses anonymity and employs a double-blind process whereby the authors and peer reviewers remain unknown or blinded to each other. Reviewers are often required to disclose conflicts of interest. The use of anonymity preserves the integrity of the peer review process and discourages favoritism shown by colleagues, friends, or relatives. Although not fool-proof, the peer review process can also maintain and enhance the quality of work by detecting flaws, plagiarism, fraud, unsound science, or personal views. Hence, the peer review process fosters scholarship and encourages authors to meet the accepted standards of their discipline.

The typical peer review process for scientific journals begins with the author submitting a manuscript. The editor of the journal reviews the article and determines whether or not the article is appropriate for the journal. If the article is determined to be appropriate, the editor assigns peer reviewers to read and critique the work. The reviewers then submit their comments to the editor and a decision is made with respect to the publication status of the article: (1) accept for publication; (2) accept for publication with modifications; (3) reject for publication (Figure 3). An average acceptance rate for publication in peer reviewed journals has been

reported to be between 25% and 50%, although journals such as New England Journal of Medicine and the British Medical Journal have been known to be much lower (Elsevier 2009).

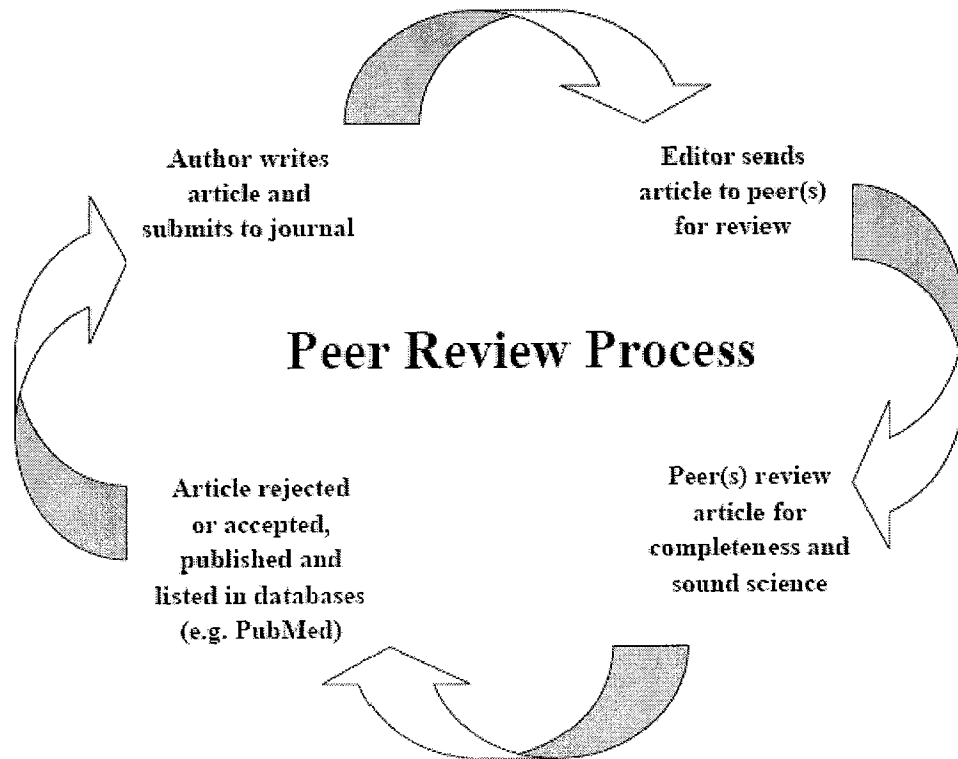


Figure 3. Peer Review Process

A thorough and complete peer review gives the reader some confidence that the article meets appropriate scientific rigor. Seldom does an article submitted for publication get accepted without addressing issues brought to light in the peer review process. At one point in time, “publication” of a scientific work in a peer-reviewed journal was a stamp of quality; however, in today’s world, opinions, ideas, and hypothesis can be “published” by a number of methods (websites, blogs, and media articles), without the scientific rigor of critical peer review.

The key aspect of the peer review is a critical appraisal of the research, a continuous challenge of the scientific hypothesis and comparison with the body of scientific knowledge relevant to

that research. While the process can never be totally free of bias (we all have opinions that influence our thinking), a clear effort to seek out those who are not directly connected to the researcher(s) is an important first step. The second part of the review process and assessment of the scientific merit of the research is the publication of the research so that others interested in the topic can benefit from the knowledge, apply it in their research efforts, or learn from the mistakes of other researchers. Opinion pieces, media interviews, court testimony, and testimony before legislative bodies, while informative, do not have the weight, standing, or status of peer-reviewed published scientific work. Unfortunately, because of their high visibility, emotional nature, and understandability, these sources outside of the peer-reviewed journals are often perceived as being of high reliability without having the benefit of careful scrutiny and response from those most knowledgeable in the research field being discussed. For example, Dr. Nina Pierpont has received a considerable amount of attention regarding the upcoming publication of her book, *Wind Turbine Syndrome: A Report on a Natural Experiment*, which uses non-traditional references such as newspaper articles and television interviews. In addition, this book is apparently being published by a publishing company which will have only one published book (this one) and that consists of an editorial board of which Dr. Pierpont and her husband make up two of the members.

Public Health Issues

“Public Health” refers to the overall wellbeing of a group of people. The description of Public Health incorporates the science of identifying major effectors of health status of a population and taking measures to prevent disease, prolong life, and promote health through private, academic, governmental, and corporate efforts. A physician treats a patient and considers the family, whereas a public health professional “examines” populations and takes broader actions to improve the health of the individuals that make up the population. Public health efforts primarily focus on prevention rather than treatment of disease. The United Nations' World Health Organization defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” This is a lofty goal to strive for, but if public health history is any indication of things to come, as we conquer the leading causes of disease, new diseases become more prominent.

There have been major successes in Public Health (e.g., smallpox eradication, control of malaria, nationwide immunization programs to prevent vaccine-preventable diseases, chlorination of municipal water supplies). However, for every public health accomplishment, there have been new health challenges related to lifestyle issues and changing health expectations. According to the U.S. Census Bureau, the final data for 2003 indicated that life expectancy at birth for the total population in America has reached an all-time high level of 77.5 years. This is up from 49.2 years at the turn of the 20th century. Record-high life expectancies were found for white females (80.5 years) and black females (76.1 years), as well as for white males (75.3 years) and black males (69.0 years). With this increase in life expectancy, there has also been an expectation of a life as free of health concerns as possible. Unfortunately, this public health progress has brought the realization of the health effects of the very activities that helped extend our lives (e.g. chlorination of drinking water, mercury-based preservatives in some vaccines).

Along with these advances has come the development of a very expansive information system called the internet, a growing environmental awareness, and a growing expectation of a long and

healthy life. The advances that have been made to support a growing and aging population have brought risks with them such as automobiles, massive highway systems, and large-city problems such as crime and pollution. These more familiar risks have been generally been accepted or forgotten, but new risks are less tolerated. Herein lays the difficulty of public health today. Population growth and societal demands have pressured public health professionals to provide guidance in the assessment of risks of new technological advancements and to reduce or eliminate risk.

While assessing a level of risk may be done in a sterile, scientific fashion, assessing the acceptability of that risk level risk becomes a preference choice. A community may choose to accept a level of risk that an individual finds unacceptable. That discrepancy between community and individual acceptability moves the decision from a public health issue to a political and social decision. Public health can bring science to the discussion, but in the end, a decision that weighs all the factors must be made for the larger group as a matter of policy.

In addition to the debate over what levels of risk are acceptable or tolerable, there is also the pressure of clearly delineating between actual risks and perceived risks. Once the analysis of the risk assessment is completed, the responsibility of the risk manager is to explain to the public and all involved stakeholders. A common perception among risk assessors and managers is that individuals who have a lack of information or information that is distorted about a risk are often subjected to unreasonable fears (Vertinsky I. And Wehrung D. 1989). These fears typically are not calmed even when accurate information is provided and unfortunately many expect a level of certainty from science that is almost always impossible to achieve. Several identified risk perception factors have been found to dictate the acceptability of risk regardless of the presentation of science which quantifies and qualifies the actual risk (Table 1).

Table 1. Risk Perception Factors For the Acceptability of Risk

“Acceptable” Risk	“Unacceptable” Risk
Controllable	Uncontrollable
Voluntary	Involuntary
Not Dread	Dread
Natural	Man-made
Beneficial	Of Little or No Benefit
Immediate Effects	Delayed Effects
Not Global Catastrophic	Global Catastrophic
Consequences Not Fatal	Fatal Consequences
Equitable	Inequitable
Affects Adults	Affects Children
Low Risk to Future Generations	High Risk to Future Generations
Easily Reduced	Not Easily Reduced
Risk Decreasing	Risk Increasing
Doesn’t Affect Me	Affects Me

Reference: (Slovic P. et al. 1982)

There are many examples in public health where the assessed risk of an event or environmental conditions is perceived differently than an interested segment of the population. In these situations, the public health officials must make the best decision they can using the scientific method. There comes a point where a decision must be made for the good of the largest segment of the population. The ramifications and effectiveness of these decisions are not always seen as positive from a historical perspective. Take for example the “Swine Flu” immunization program of 1976 under the Ford Administration. That program resulted in a segment of the immunized population developing Guillain-Barre Syndrome. The same sort of decision process is being carried out now as public health officials embark on a campaign to protect the population for an H1N1 Pandemic. Part of the analysis included an estimation of how many persons can be expected to develop Guillain-Barre Syndrome from the new vaccine.

Societal decisions, like Public Health decisions, must be made with the benefit of the best, most sound information. Few historical efforts to advance health or societal development have come without concerns from many segments of the population and a few that may be affected.

Precautionary Principle

Some groups and organizations have addressed the acceptability of risk by adopting a position or philosophy that when risk may exist, but the level of risk is in doubt, actions should be taken to avoid the risk much in tune with the idea that “if in doubt, don’t.” Similarly, a process potentially producing risk is “guilty until proven innocent.” This view is commonly referred to as the “precautionary principle.” While seemingly attractive, the precautionary principle fails to acknowledge that in reality, every human activity has risk, and the balance between the potential risk and the value of that activity depends on the individual.

The precautionary principle is an attempt to set a goal for environmental planning and response to perceived health threats based less on science and more on the social basis of the issue being examined. While the principle was developed during the discussion of environmental issues, it can be applied to any function of mankind and all our activities. It is a high standard to compare activities of the earth’s inhabitants based on social values and less on science. There are few arguments when a solid body of science has been amassed showing an association and meeting the criteria for “causation.” The difficulty arises when new discoveries and applications are evaluated on what effect they “could have” rather than on the scientific data obtained during their development and regulatory review. The philosophy of “new is not necessarily good” and the “fear of the unknown” result in an almost instant increased level of concern in a segment of most populations. This is partially due to the easy access to information provided by media and the internet, the risk aversion that has become prevalent in our society, and the pressures of our evolving societies. The precautionary principle should be applied in the light of the science of the day and with the understanding that no scientific study of a sample of the population can “prove” there is no association between a technology and a perceived health threat.

The precautionary principle has evolved in both the legal and social context to the point of being prominent in national and international treaty and agreements. While the principle incorporates an extremely cautious approach, it embodies concepts that we have embraced in

our daily lives e.g. “an ounce of prevention is worth a pound of cure,” “look before you leap,” and “better safe than sorry.” On an individual basis, the precautionary principle is relatively easy to apply, and the risk and benefit directly applies to the individual. Application of the precautionary principle at a community or national level involves societal decisions that may include legal, economic, and political aspects. The application of the scientific process and sharing of knowledge gained through scientific investigation can provide objective information to assist in these decisions. Science will reduce the uncertainty, but not eliminate it entirely. Society must decide what is an acceptable level of risk (e.g. allowing passengers to fly in airplanes without parachutes, allowing people to ride ferryboats without wearing lifejackets). Delineation and comparison of risk is a scientific process, but determination of acceptable risk is beyond the realm of science.

Background on Infrasound and Low Frequency Sound

Sound is an energy generated by a source (e.g., bell), transmitted through a medium (e.g., air), and received by a receiver (e.g., human ear). Sound travels from the source in the form of waves or fluctuations of pressure within the medium. As the human ear detects these vibrating waves, they are translated into electrical signals that are transmitted to the brain for decoding.

Sound is perceived and recognized by its loudness (pressure) and pitch (frequency). The indicator of loudness is the decibel (dB), which is a logarithmic ratio of sound pressure level to a reference level.¹ With a logarithmic scale, sound levels from two or more different sources cannot be arithmetically added together to determine a combined sound level. Specifically, the dB is a logarithmic unit of measurement that expresses the magnitude of a physical quantity such as power or intensity relative to a specified reference level. Human hearing of sound loudness ranges between 0 dB (threshold of sound for humans) and 140 dB (very loud and painful sound for most humans) (NMCPHC 2009; NASD 1993) (Table 2). Not all sound pressures are perceived as being equally loud by the human ear due to the fact that the human ear does not respond equally to all frequencies. The frequency range of human hearing has been found to be between 20 Hz and 20,000 Hz for young individuals with a declining upper frequency range correlating with increasing age (Berglund B. et al. 1996). The frequency of sound is expressed in Hertz (Hz)² which is equal to 1 cycle per second. The sound perception, “hearing,” for humans is less sensitive to lower frequency (low pitch) and higher frequency (high pitch) sounds. As a result, the human ear can most easily recognize sounds in the middle of the audible spectrum, which is ideally between 1 kHz to 4 kHz (1,000 to 4,000 vibrations per second) (UNSW 2005). As a result, devices used to measure sound (sound meters³) are

¹ Reference Level - A special value of a quantity expressing the degree of modulation of a recording medium, in terms of which other degrees of modulation are expressed, usually in decibels (IEC).

² Hertz (Hz) - A unit of frequency defined as the number of cycles per second (1 Hz equals 1 cycle per second). Hertz can be used to measure any periodic event within a sinusoidal context, such as radio and audio frequencies (IEC).

³ Sound Level Meter – Instrument used for the measurement of sound level with a standard frequency weighting and a standard exponential time weighting (IEC).

designed with filters that have a response to frequency similar to human. The A scale is the most commonly used sound level filter and the sound pressure level is given in units of dB(A) or dBA. With the A weighting filter, the sound level meter is less sensitive to very high and very low frequencies. Sound measurements made on the C scale, which are linear over several octaves and suitable for subjective measurements of very high frequency sound levels, are expressed as dB(C) or dBC. Another weighting filter, the B scale, is a rarely used intermediate between the A and C scales (UNSW 2005).

Table 2. Human Sound Intensity Levels

Decibel Level (dB)	Source
140	Threshold of pain: gunshot, siren at 100 feet
135	Jet take off, amplified music
120	Chain saw, jack hammer, snowmobile
100	Tractor, farm equipment, power saw
90	OSHA limit - hearing damage if excessive exposure to noise levels above 90 dB
85	Inside acoustically insulated tractor cab
75	Average radio, vacuum cleaner
60	Normal conversation
45	Rustling leaves, soft music
30	Whisper
15	Threshold of hearing
0	Acute threshold of hearing

Reference: (NASD 1993)

In the 1930s, researchers Fletcher and Munson conducted experiments on the response of the human ear and the relationship between sound frequency and pressure (Fletcher H. and Munson WA. 1933). Fletcher and Munson developed curves to approximate this relationship which were then revised by the International Organization for Standardization (ISO) and are now referred to as Normal Equal-Loudness Level Contours. Hence, an equal-loudness contour is a measure of the sound pressure (dB) level required to cause a given loudness for a listener as a function of frequency (Hz) (Figure 2).

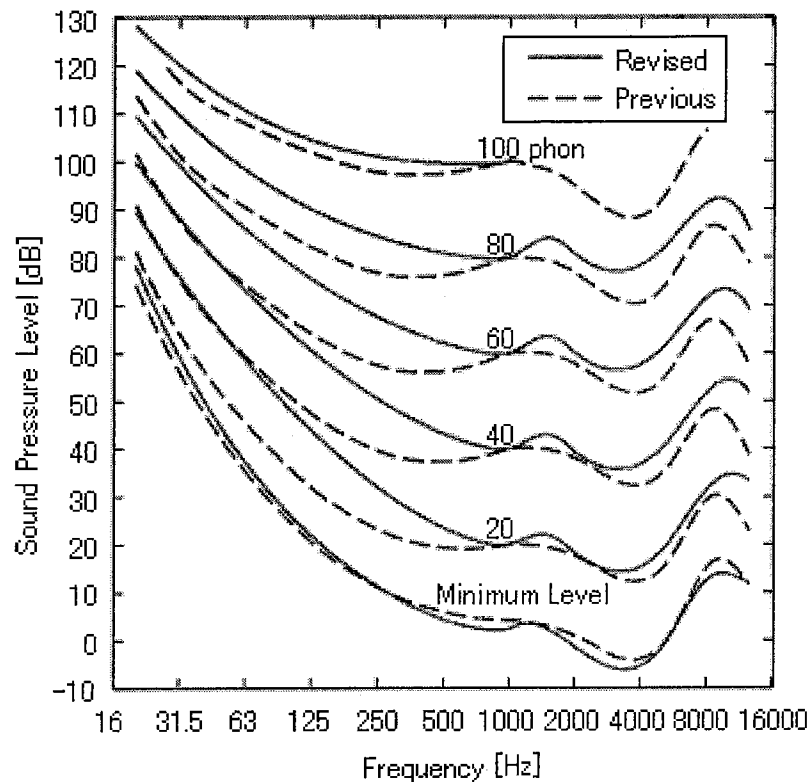


Figure 4. Normal Equal-Loudness Level Contours

Infrasound

Infrasound is generally accepted to be sound between 0 Hz and 20 Hz (Leventhall G. 2007) (Table 3). Infrasound occurs when the frequency of acoustic oscillations (Hz) is lower than the low frequency limit of audible sound, which is approximately 16 Hz according to the International Electrotechnical Commission (IEC) (Leventhall 2007). Although the human hearing threshold has been found to be as low as 4 Hz in an acoustic chamber, a level of 20 Hz, arises from the lower frequency limit of the Normal Equal-Loudness Level Contours. At 1,000 Hz, the contour ranges a span of 100 dB, but at lower frequencies the contours are grouped more closely together. Thus, the change of grouping at 20 Hz or below leads to a greater rate of growth in loudness with increasing level for frequencies in the infrasound region (Leventhall G. 2007).

Although it has been believed that infrasound is inaudible, that belief has been determined to be a misconception (Berglund B. et al. 1996; Leventhall G. 2007; Maschke C. 2004). Infrasound at frequencies lower than 20 Hz are audible at very high levels and these sounds may occur from many natural sources, such as meteors or volcanic eruptions. Anthropogenic (i.e., human-caused) sources, which often are the predominant type of source, can also generate infrasonic noise and include machinery, ventilation, or large combustion processes (Berglund B. et al. 1996; Leventhall G. 2007; Sienkiewicz Z. 2007). In addition, the human body has multiple sources of sound. For example, heart sounds are in the range of 27 to 35 dB at 20-40 Hz (Sakai A. et al. 1971) and lung sounds are reported in the range of 5-35 dB at 150-600 Hz (Fiz JA. Et al. 2008).

The threshold of human hearing has been found to be well in the range of infrasound, but it has been suggested that detection does not occur through hearing in the normal sense. Infrasound detection has been theorized to result from nonlinearities of conduction in the middle and inner ear which produces a harmonic distortion in the higher frequency range (Berglund B. et al. 1996). Also, the definition of infrasound detection has not only considered direct hearing, but also subjective reactions such as annoyance as well as detection occurring through the resonance of other body organs (Berglund B. et al. 1996).

Table 3. Sound Frequency Spectrum

Frequency (Hz)				
0	10	20	100/250	20,000
Infrasound (With Body Resonance)	Infrasound	Low Frequency Sound	Non-Low Frequency Audible Sound	Ultrasound

Low Frequency Sound⁴

The low frequency sound range is approximately between 10 or 20 Hz and 100 or 250 Hz (Berglund B. et al. 1996). The setting of a lower and upper limit of a continuum has been

⁴ The word "sound" and "noise" are terms that can be used interchangeably. "Noise" often implies an unwanted sound. The use of "noise" also depends on the intensity of the sound or the complex temporal pattern. The classification of a "sound" or "noise" may also depend of cultural factors, the individual, or the time and circumstance (Berglund B. et al. 1996).

problematic due to the arbitrary nature of setting those limits. However, it has generally been accepted that low frequency sound is below 100 Hz (Takahashi Y. et al. 2005) or 200 Hz (Maschke C. 2004). Due to the long wavelengths of low frequency noise, it has been known to travel long distances and pass through walls and windows with little attenuation (Waye K. 2004).

With respect to reception, the hearing sensitivity of the human ear declines at low frequencies (Takahashi Y. et al. 2005). Occupational and residential activities have been found to be a common source of low frequency sound (Berglund B. et al. 1996). Many sources of low frequency noise are transportation vehicles such as buses, trains, and some aircraft. Other stationary sources of low frequency noise include heating, cooling, or ventilation of buildings (Waye K. 2004). Low frequency sound possesses features that are not commonly shared by higher pitch noises.

A review of the literature related to sound indicates that there are uncertainties associated with the measurement and characterization of low frequency sound. As mentioned previously, the A scale is the most commonly used sound level filter (Sienkiewicz Z. 2007; Takahashi Y. et al. 2005; Takahashi Y. et al. 2001; Takahashi Y. et al. 1999). Furthermore, it was recommended that either a scale with a more appropriate response be developed and used for characterizing low frequency sound or that the details of the acoustic environment be provided for each exposure scenario (Sienkiewicz Z. 2007).

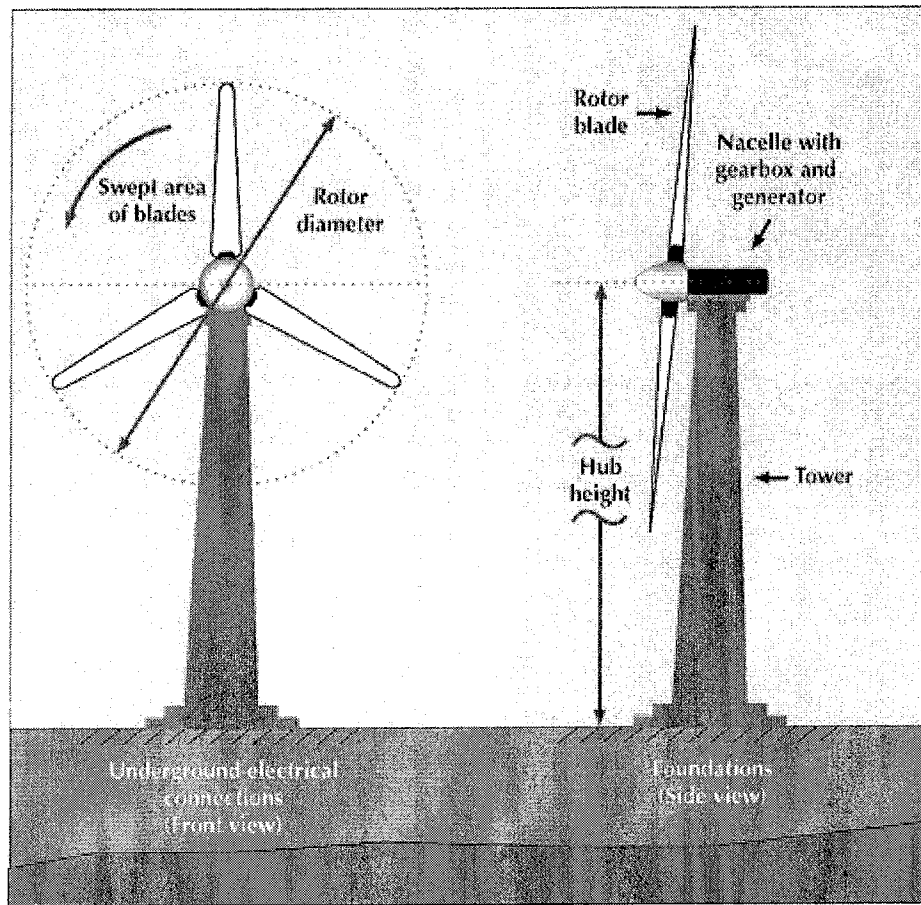
As mentioned previously, human hearing becomes less sensitive for decreasing frequency. In addition to the sensitivity of sound, the perceived character of that sound also changes at lower frequencies. The threshold⁵ for hearing is standardized by ISO for frequencies down to 20 Hz, but there has been research and some agreement among investigators regarding a possible threshold for frequencies below this level (Moller H. and Pedersen CS. 2004). Men and women have the same hearing threshold with the standard deviation between individuals being

⁵ Threshold - For a specified signal and method of presentation, amount in decibels by which the threshold of hearing for a listener, for either one or two ears, exceeds a specified standard threshold of hearing (IEC).

approximately 5dB. Furthermore, low frequency sound may be inaudible to some, but that same sound may be loud to others.

Background on Wind Turbines and Noise

There are two types of noise generated from wind turbines. One is a mechanical noise originating from the gearbox, generator, and yaw motors. The other type of noise, aerodynamic noise, originates from the flow of air around the components of the wind turbine (blades and tower) produces a “whooshing” sound in the range of 500 to 1000 Hz (Hau E. 2006). This type of noise is typically the dominant component of wind turbine noise because manufacturers have been able to reduce the mechanical noise to a level that is below the aerodynamic noise (Pedersen E. and Waye KP. 2004). However, the whooshing sound is highly variable and dependent upon mechanical as well as atmospheric conditions. Hence, the sound power levels reached by wind turbines are determined by the mechanical and aerodynamic specifications.



www.retscreen.net

Figure 5. Horizontal Axis Wind Turbine

Evaluation of Scientific Literature on Health Effects

A thorough search was performed of the peer-reviewed scientific literature using the PubMed⁶ search engine which is maintained by the United States National Library of Medicine. The purpose of the search was to identify literature that has addressed the known or unknown health effects associated with infrasound and low frequency sound. The following search criteria terms were used for each search query with some overlapping results.

Table 4. Literature Search Queries

Search Query	Number of Articles Found
Infrasound AND Health Effects	16
Low-Frequency Noise AND Health Effects	59
Low-Frequency Sound AND Health Effects	40
Wind Power AND Noise	18
Wind Turbines	20
Wind Turbines AND Noise	3
Total	156

In 2003, the U.S. Environmental Protection Agency (EPA) published a document entitled “A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information” which outlined general assessment factors to evaluate the quality and relevance of scientific and technical information (U.S. EPA 2003). The assessment factors include (1) soundness; (2) applicability and utility; (3) clarity and completeness; (4) uncertainty and variability; and (5) evaluation and review. These factors use a weight-of-evidence approach that considers the information provided in an integrative assessment. These factors also take into account the quality and quantity as well as the strengths and weaknesses of the information. These EPA guidelines were used to evaluate the articles identified in this literature search.

⁶ Pub Med is a searchable database that comprises more than 19 million citations for biomedical articles from MEDLINE and life science journals.

Applicability and Utility

The extent to which the information is relevant for the intended use, or how relevant the study is to current conditions of interest (U.S. EPA 2003).

With each identified article, the research and research subjects were ranked as a whole based on the applicability to the overall purpose of the literature search. The following ranking system was employed, and then we eliminated articles with a rank of one or two from further review (Table 6). These ratings and those used in later tables were also used in the appendix. Although it has been found in animal experiments, during the last 50 years, that high levels of low frequency noise and vibration can influence the respiratory rate, cardiac, digestive and central nervous systems, (Maschke C. 2004) animal studies were not reviewed in this white paper. At this time only human studies were reviewed and evaluated, which also eliminated articles with a rank of three. It was assumed that animal studies would not provide the necessarily applicability to effects of wind turbines on humans, thus resulting in an extrapolation layered with assumptions. Articles that were not written in the English language were also eliminated. Background research consisted of articles that reviewed infrasound and low frequency sound in general.

Table 5. Applicability and Utility Ranking System

Rank	Rank Description
1	No applicability at all
2	Limited applicability (e.g. <i>in vitro</i> studies)
3	Some applicability (e.g. animal studies)
4	Applicable (e.g. human studies)
5	Very applicable (e.g. human studies and wind turbines)
**	Background research

Soundness

The extent to which the scientific and technical procedures, measures, methods or models employed to generate the information are reasonable for, and consistent with, the intended application (U.S. EPA 2003).

The articles were evaluated based on whether or not the study purpose was reasonable and consistent with its design. If articles did not employ sound scientific theory or accepted approaches, such as the use of an adequate sample size or the validation of a survey instrument, they were graded accordingly.

Table 6. Soundness

Rank	Rank Description
1	Not sound (e.g. study instrument not validated)
2	Sound with limitations (e.g. useful research but not consistent with design)
3	Very sound (e.g. study reasonable and consistent with design)
**	Background research

Clarity and Completeness

The degree of clarity and completeness with which the data, assumptions, methods, quality assurance, sponsoring organizations and analyses employed to generate the information are documented (U.S. EPA 2003).

Articles were assessed for clarity and completeness and whether or not the results were clearly described and comparable to other study results. The description of the study design and methods was also assessed to determine if the description was clear enough for reproducibility.

Table 7. Clarity and Completeness

Rank	Rank Description
1	Several limitations
2	Complete with some limitations
3	Very complete (e.g. clear enough to be reproduced)
**	Background research

Uncertainty and Variability

The extent to which the variability and uncertainty (quantitative and qualitative) in the information or in the procedures, measures, methods or models are evaluated and characterized (U.S. EPA 2003).

The level of uncertainty and variability of the study methodology and results and how these uncertainties were handled were also evaluated. Potential sources of error and study bias were considered as well.

Table 8. Uncertainty and Variability

Rank	Rank Description
1	High uncertainty and variability
2	Medium uncertainty and variability
3	Low uncertainty and variability
**	Background research

Evaluation and Review

The extent of independent verification, validation and peer review of the information or of the procedures, measures, methods or models (U.S. EPA 2003).

Independent verification was measured by whether or not the methodology used and survey instruments were used on other similar, peer-reviewed studies. The consistency of the results with other relevant studies performed by the same or different authors was also accounted for in this analysis.

Table 9. Evaluation and Review

Rank	Rank Description
1	Low validation (e.g. no independent verification or similar results)
2	Medium validation (e.g. result consistent with same author)
3	High validation (e.g. results consistent in peer-review literature)
**	Background research

Final Included Literature

Of the original 156 articles identified, 21 were included for the literature review (Appendix A). Based on the previously outlined five assessment factors, the most relevant and scientifically appropriate articles were selected for this review. Many articles were excluded from this review due to the fact that the research focused in animal responses as opposed to human. Furthermore, with the exception of articles dealing with annoyance, articles were excluded if the sound studied was above the established range of low frequency sound.

Health Effects of Infrasound and Low Frequency Sound

Human Effects

It has been demonstrated that high levels of low frequency sound can excite body vibrations, such as a chest resonance vibration that can occur at a frequency of 50 Hz to 80 Hz (Leventhall G. 2007). These chest wall and body hair vibrations have also been shown to occur at the infrasonic range (Mohr GC. et al. 1965; Schust M. 2004). It is of interest to note that various body organs and physical activities of the human body produce low frequency, low amplitude sounds, some of which are key diagnostic tools for physicians (e.g., heart, lung, and gastrointestinal).

Vibroacoustic disease, a thickening of cardiovascular structures, such as cardiac muscle and blood vessels, was first described and documented by Castelo Branco *et al.* among airplane technicians, commercial and military pilots, mechanical engineers, restaurant workers, and disc jockeys for exposure to large pressure amplitude and low frequency (LPALF) sound ($> \text{or} = 90 \text{ dB SPL}$, $< \text{or} = 500 \text{ Hz}$) (Maschke C. 2004; Castelo Branco NA. and Rodriguez E. 1999). Castelo Branco *et al.* concluded that workers who were exposed to high level low frequency noise for more than 10 years exhibited extra-aural⁷ symptoms such as thickening of heart valve issue (Castelo Branco NA. and Rodriguez E. 1999; Takahashi Y. et al. 2001; Maschke C. 2004). However, this association was not determined to be causally related and a dose response relationship was not established.

Takahashi *et al.* has explored the effects of acoustic excitation by measuring the resulting vibration (Takahashi Y. et al. 1999; Takahashi Y et al. 2001; Takahashi Y. et al 2005). In 1999, six male subjects were exposed to pure tones in the 20 Hz to 50 Hz frequency range, and vibration was measured on the subjects' chest and abdomen. There were 15 kinds of the low frequency noise stimuli (5 frequencies x 3 sound pressure levels) reproduced by loud speakers.

⁷ Aural - Of or relating to the ear or to the sense of hearing

All of them were pure tones frequencies of 20, 25, 30.5, 40 and 50 Hz with each of the corresponding sound pressure levels of 100, 105 and 110 dB (SPL).

It was found that measured noise induced vibration negatively correlated with the subject's body mass index and the researchers concluded that the health effects of low frequency noise depended on the physical constitution of the human body (Takahashi Y. et al. 1999). However, it was also concluded by the researchers that it was still unknown if or how vibrations measured on the body surface related to vibrations in the body's internal organs, and that no conclusions could be determined as to the possible chronic health effects caused by long term exposure to low frequency noise (Takahashi Y. et al. 1999). Similarly, in a later article, Takahashi *et al.* reported that low frequency noise (same frequency and sound pressure levels as previously reported) induced vibration measured on the chest was higher than the vibration measured on other parts of the body (Takahashi Y. et al. 2001). By taking this research a step further; Takahashi *et al.* examined the level of unpleasantness of human body vibration and low frequency sound (same frequency and sound pressure levels as previously reported). It was found through the use of a rough rating scale for subjective unpleasantness that there was a significant correlation between the measured body surface vibration induced by the low frequency noise and the rating of unpleasantness (Takahashi Y. et al. 2005). This finding was similar to research conducted by Inukai *et al.*, who discovered that the slopes of the equal-unpleasantness level contours are very similar to those of the equal-loudness level contours. This similarity supported the fact that hearing sensation was an influential component in the perception of unpleasantness or annoyance among those exposed to low frequency noise (Inukai Y. et al. 2000; Takahashi Y. et al. 2005). This perception of unpleasantness was also determined to be independent of the audibility of the noise (Takahashi Y. et al. 2005). Inukai *et al.* also recognized the fact that the human psychological responses to low frequency noise, such as unpleasantness or annoyance, were based not only on hearing sensation, but also on three other factors: sound pressure, vibration, and loudness (Inukai Y. et al. 1986; Takahashi Y. et al. 2005).

In a general review of the effects of low frequency noise up to 100 Hz, Schust stated that the use of frequency weighting with an attenuation of low frequencies, such as G-weighting, was not appropriate for evaluating the health risk caused by low frequency noise (Schust M. 2004). Karprova *et al* (1970) ((5, 10 Hz / 100, 135 dB) for 15 minutes) and Slarve *et al.* (1975) (144 dB / 1 Hz - 20 Hz for 8 minutes) also indicated that study subjects reported aural complains after exposure to high level industrial infrasound in the range of 1 Hz to 20 Hz (Karprova NI. et al. 1970; Schust M. 2004; Slarve RN. and Johnson DL. 2009). Non-aural effects, such as a significantly increased diastolic blood pressure and decreased systolic blood pressure, were also mentioned after exposure to high levels of low frequency noise (125 dB, 16 Hz for 1 hour) (Danielsson A. and Landstroem U. 1985; Schust M. 2004). Karprova *et al* also reported complaints of fatigue, feelings of apathy, loss of concentration, somnolence, and depression following exposure to high levels of low frequency noise (5 Hz and 10 Hz (100 dB and 135 dB) for 15 minutes) (Karprova NI. et al. 1970; Schust M. 2004). Furthermore, the effects of low frequency noise among 439 employees working in offices, laboratories, and industries were also evaluated in another study. It was shown that there was a relationship between fatigue and tiredness after work and increasing low frequency noise. There were no employees that were exposed to low frequency noise with C-A differences greater than 20 dB (Schust M. 2004; Tesarz M. et al. 1997).

Ising *et al.* conducted a study that examined the effect of low frequency nighttime traffic noise by measuring saliva cortisol concentrations in children. Based on a previous study, the authors stated that the full spectrum of truck noise in the children's bedroom was at a maximum of 100 Hz (Ising H. et al. 2004; Ising H. and Kruppa B. 2004). It was found that the children under high noise exposure (8h = 54-70dB(A)) had a significantly increased morning saliva cortisol concentration compared to a control population, which indicated an activation of the hypothalamus-pituitary-adrenal (HPA) axis (Ising H. et al. 2004). This endocrine change was found to be an indication of restless sleep and a further aggravation of bronchitis in the children.

Finally, in 2000, a multidisciplinary group of clinicians and researchers called the Study Group on Neonatal Intensive Care Unit (NICU) Sound and the Expert Panel gathered and reviewed

over 50 studies on the effects of sound on the fetus, newborn, and preterm infants. Upon the completion of review, the panel recommended that women should avoid prolonged exposure to low frequency sound levels (< 250 Hz) above 65 dB(A) during pregnancy (Graven SN. 2000). This recommendation was based on research that was conducted on sheep fetuses, which determined that after sustained periods of intense low frequency sound, the fetuses experienced injury to the hair cells of cochlea (Graven SN. 2000).

There have been some studies that have looked at the effect of low frequency noise on nighttime sleep (Maschke C. 2004). Unfortunately, for many of these studies, it was difficult to determine what percentage of the nightly noise was actually low frequency noise. Case studies have reported that low frequency noise (low-frequency noise reaching levels between 72 and 85 dB(A)) affects sleep quality and results in insomnia and concentration problems (Berglund B. et al. 1996; Waye K. 2004). A cross-sectional study of 279 individuals, it was determined that there were no significant differences detected in reported sleep among those exposed to flat frequency noise (>100 Hz; 24 to 33 dBA and 41 to 49 dBC) in their homes as compared to low frequency noise (50 Hz – 200 Hz; 26 to 36 dBA and 49 to 60 dBC) from ventilation and heat pumps (Persson Waye K. and Rylander R. 2001; Waye K. 2004). However, it was determined that fatigue, difficulty falling asleep, feeling tense and irritable were reported significantly more often among those individuals who were annoyed by low frequency noise than those who were exposed to the same noise but did not report being annoyed. Additionally, a dose-response relationship was identified between reported annoyance/disturbed rest and degree of low frequency noise before and after correction for differences in A-weighted sound pressure levels (Persson Waye K. and Rylander R. 2001; Waye K. 2004). In another study, six individuals were exposed to sinusoidal tones as 10, 20, 40, and 63 Hz with sound pressure levels ranging from 75 to 105 dB for 10 Hz and 20 Hz and 50 to 100 dB for 40 Hz and 63 Hz. No significant difference was found between the exposure and control nights in sleep efficiency index, number of changes in sleep state, or changes in the proportion of each sleep stage evaluated by electroencephalogram recordings (Inaba R. and Okada A. 1988; Waye K. 2004).

Annoyance

The World Health Organization (WHO) definition of the adverse effects of noise is as follows:

Change in the morphology and physiology of an organism that results in impairment of functional capacity to compensate for additional stress, or increases in the susceptibility of an organism to the harmful effects of other environmental influences. Includes any temporary or long-term lowering of the physical, psychological or social functioning of humans or human organs (WHO 2001).

An earlier definition of annoyance was "a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them" (Koelega HS.(ed.) 1987; Lindvall T. and Radford EP.(eds.) 1973; WHO 1999). The WHO considers annoyance an adverse health effect of noise in addition to sleep disturbance, performance effects, and psychological effects such as irritability (WHO 2001). Annoyance was also defined as a feeling of displeasure with varying tolerance levels. WHO also characterized annoyance as a feeling that increases with noise impulses as opposed to a steady noise (WHO 2001).

As specifically related to low frequency noise generated from wind turbines, Pedersen *et al.* noted a dose response relationship between calculated A-weighted sound pressure levels from wind turbines and noise annoyance in a cross-sectional study that was conducted in five dwelling areas in Sweden. It was determined that the study respondents were annoyed by the wind turbines at a higher level than other community noises, such as road traffic (Pedersen E. and Waye KP. 2004). It was also found the noise annoyance was related to visual or aesthetic interference, and attitude or sensitivity toward to wind turbine (Pedersen E. and Waye KP. 2004). Importantly, it should be noted that the Swedish wind turbines were all upwind devices which had a blade passage frequency of 1.4 Hz, but unlike earlier downwind turbines which contained low frequency noise, these turbines had upwind rotor blades and the noise was much more broadband (Pedersen E. and Waye KP. 2004).

In addition to annoyance, the relationship between wind turbine noise and self-reported health and well-being factors was also researched by Pedersen *et al.* It was confirmed that there was no correlation between A-weighted sound pressure levels from wind turbines and any health or

well-being factors, such as the respondent's status of chronic disease, diabetes, or cardiovascular disease (Pedersen E. and Persson, Waye K. 2007). However, among the 31 respondents who stated that they were annoyed by the wind turbine noise, out of 754 respondents, 36% reported that their sleep was disturbed and 19% reported being tired (Pedersen E. and Persson, Waye K. 2007). Both of these findings were statistically significantly higher in comparison to those respondents who were not annoyed. Recall bias is likely to occur among annoyed individuals, and it is not apparent that this bias was considered in this study. Furthermore, Pedersen *et al.* also identified that living in a rural area, as opposed to an urban area, increased the risk of perceiving wind turbine noise and being annoyed by it (Pedersen E. and Persson, Waye K. 2007).

The underlying complaint of annoyance is, in and of itself, not a disease or a specific manifestation of a specific exposure, but instead a universal human response to a condition or situation that is not positively appreciated by the human receptor. The variability of annoyance and its link to undesirable factors makes it a prime indicator for the possibility of recall bias. Annoyances are highly variable in types (noise, smell, temperature, taste, vision) and vary from person to person. One can be annoyed by the action of others as well as their own individual actions. Thus "annoyance" is not a disease but a human response that is highly non-specific.

Disease vs. DIS-ease

The state of being in which individuals are uneasy, agitated or without ("dis") freedom from labor, pain, anxiety or physical annoyance ("ease") can often be undistinguishable from the state of disease as related to morbidity. Both states of being can be assessed objectively and subjectively. However, with physical illnesses, objective measureable indicators can be obtained through instrumentation testing that is typically absent of human error or influence. Subjective responses to stimuli are much harder to prove or disprove which is why it is very important to supplement a subjective response with an objective assessment.

Limitations of Scientific Literature

The research and scientific literature on the human health effects of low frequency noise exposure are limited. Most researchers have agreed that there are some uncertainties associated with the measurement and characterization of low frequency sound. The most important limitation of the current research involves the use of the A-weight scale. The WHO and other researchers have stated that the conventional method of using an A-weighted equivalent sound level may be inadequate for low frequency noise. There are other researchers who advocate that the current research using various weighted measures is sufficiently robust to be depended upon for the evaluation of the potential for sound related health effects. As a result of these diverse opinions, biased or conflicting conclusions may have been made about the level of low frequency sound and its human health effects.

Another significant limitation of the current research is the use of a small number of subjects or those with prejudicial views of wind turbines. Although it was noted in some studies that the questionnaires used were masked, it was quite possible the participants still had negative or unfavorable attitudes about the wind turbines and the low frequency noise that was generated. The presence of wind turbines has instigated heightened levels of annoyance and NIMBY (*Not In My Back Yard*) attitudes by the nearby residents. With such levels of annoyance and discontent, it is very plausible that the associated anxiety can engender health effects or amplify already existing health conditions. It would be beneficial to examine the health effects of low frequency noise among residents that did not experience the annoyance of the presence of wind turbines. There are health effects and adverse health effects and it is important to differentiate the between the two types of effects.

A common effect that has been observed with low frequency noise is vibration. Although the effects of low frequency noise and vibration have not been well characterized, objective body vibration results only from very high levels of low frequency noise, greater than those produced by wind turbines. Sleeplessness and insomnia have also been associated with low frequency

noise, but this finding has been poorly correlated and lacking in consistency. However, the level of annoyance with low frequency noise was found to be correlated with insomnia.

Conclusions

Noise exposures outside the workplace have not been studied as extensively as those that occur in the workplace. There have been pockets of research centering on population exposures to highway traffic noise, noise exposures associated with living near commercial airports, and a scattering of other community noise sources, but there is not an extensive amount of research specifically on the health effects related to the sound exposure generated by wind turbines. However, wind turbines have been used in the U.S. since the late 1800s that has provided a baseline of knowledge and experience of their usage and presence in American lives. The first windmill for electricity production in the United States was built in Cleveland, Ohio by Charles Brush (Windpower.org 2003). In addition, wind turbines have continued to evolve (e.g. vertical to horizontal designs, downwind to upwind blade positioning and numerous sound reduction design changes with the mechanics of the turbine.) This evolution of design and the use of improved technology have resulted in quieter and more efficient wind turbines. Possibly the biggest change beyond these design changes is the trend to build more wind farms.

The implementation of wind turbines has resulted in a steadily growing population of individuals who live in their geographical and visual proximity. The literature clearly delineates a subset of this population that is annoyed by the nearby presence of wind turbines, but there has not been a specific disease or condition that has been found by the research community to be caused by the wind turbines. However, there have been illnesses, symptom complexes, and other health events attributed to wind turbines. This is to be expected given the circumstances and emotions that often surround the presence of wind turbine farms. This is a common phenomenon that is associated with activities that are perceived as a social disruption or infringement on personal rights or freedom.

The literature, both scientific and lay, clearly indicates the diversity of concerns regarding the presence of wind turbines near residences and communities. The science of sound is robust and has identified a number of health-related links to high level industrial sound in the workplace. This same science has not identified a causal link between any specific

health condition and exposure to the sound patterns generated by wind turbines of the type used today, perhaps because they generate far lower decibel levels than most vocational sources. However, the same science has determined that there is a range of sounds (some would say noise) that is clearly described by some as annoying. The process of being annoyed is a universal response that is not specific to wind turbines. The nonspecificity of annoyance leads to confusion and concern that the peer reviewed published scientific literature has not been able to adequately clarify. It appears that the scientific process of research and discussion before acceptance of new principles, or redefinition of previously accepted principles, has to some extent gotten caught up in rush of the lay media. Jumping from observations and speculation to cause and effect has been the result of this rush. This type of short cut has historically led to misdirection of resources and efforts.

The subjective nature of annoyance makes the job of epidemiological investigation difficult due to the biases that this subjectivity brings to any study. One cannot assess the level of effect of an activity by analyzing the experience and perceptions of those who are annoyed, without an appropriate comparison group and study design that reduces or delineates the biases that commonly hamper studies of emotionally-charged activities such as the positioning of wind turbines.

Believing without question can lead to positions of unnecessary vulnerability. It is often stated that the best advocate for a patient's rights, well-being and infallible medical care is the actual patient. Therefore, second medical opinions are often highly recommended despite who is giving the first opinion or what that opinion may be. Likewise, the rush to accept opinions without an adequate scientific or medical basis (e.g. objective medical tests) may actually lead to adverse health outcomes originating from the perception of health effects. From the positive perspective, there can be a healing effect or belief, as in the "placebo effect", which is often a key part of a medical encounter. Unfortunately, the reverse can also occur in the situation where a person is given "bad health news" that is unfounded or incorrect and person actually becomes physically and/or emotionally ill. It

is a delicate balance that must be maintained as health care professionals and public health officials weigh the science in making decisions.

Based on the literature review that was conducted for this white paper, there was not any scientifically peer-reviewed information found demonstrating a link between wind turbines and negative health effects.

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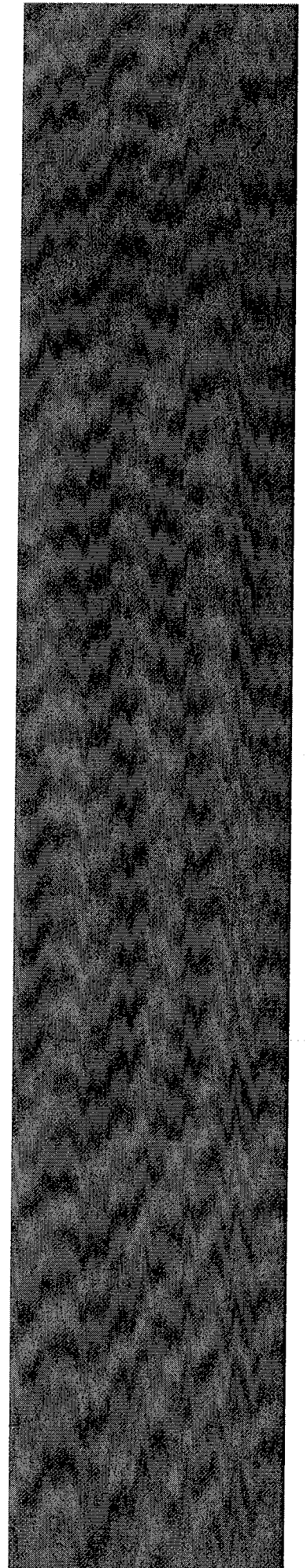
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Appendix A

Final Literature



List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
Search Term: Infrasound AND Health Effects										
1	2007	Sienkiewicz Z.	Rapporteur report: Roundup, discussion and recommendations.	Prog Biophys Mol Biol.	**	**	**	**	**	
2	2007	Leventhall G.	What is infrasound?	Prog Biophys Mol Biol.	**	**	**	**	**	
3	2004	Feldmann J. et al.	Effects of low frequency noise on man--a case study.	Noise Health.		4				x
4	1999	Pawlaczyk-Luszczynska M.	Evaluation of occupational exposure to infrasonic noise in Poland.	Int J Occup Med Environ Health.		4				x
5	1996	Pawlaczyk-Luszczynska M.	Infrasound in the occupational and general environment: a three-element microphone measuring method for locating distant sources of infrasound.	Int J Occup Med Environ Health.		4				x

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
Search Term: Low-Frequency Noise AND Health Effects										
6	2005	Hori K. et al.	Influence of sound and light on heart rate variability	J Hum Ergol (Tokyo).		4				x
7	2005	Takahashi Y et al.	A study on the relationship between subjective unpleasantness and body surface vibrations induced by high-level low-frequency pure tones.	Ind Health.	2	4	2	2	2	
8	2004	Schust M. et al.	Effects of low frequency noise up to 100 Hz	Noise Health.	**	**	**	**	**	
9	2004	Ising H. et al.	Low frequency noise and stress: bronchitis and cortisol in children exposed chronically to traffic noise and exhaust fumes	Noise Health.	1	4	1	1	2	

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
10	2002	Silva MJ. et al.	Low frequency noise and whole-body vibration cause increased levels of sister chromatid exchange in splenocytes of exposed mice.	Teratog Carcinog Mutagen.	2	3	2	1	1	
11	2001	Takahashi Y et al.	A new approach to assess low frequency noise in the working environment	Ind Health.	2	4	1	2	1	
12	2000	Graven SN.	Sound and the developing infant in the NICU: conclusions and recommendations for care	J Perinatol.	**	**	**	**	**	
13	1999	Silva MJ. et al.	Sister chromatid exchange analysis in workers exposed to noise and vibration	Aviat Space Environ Med.		4				x
14	1999	Alves-Pereira M.	Noise-induced extra-aural pathology: a review and commentary	Aviat Space Environ Med.		4				x

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
15	1999	Takahashi Y et al.	A pilot study on the human body vibration induced by low frequency noise	Ind Health.	2	4	2	2	1	
16	1996	Berglund B. et al.	Sources and effects of low-frequency noise.	J Acoust Soc Am.	**	**	**	**	**	
17	1993	Seidel H.	The problem of a "vibration disease" caused by low-frequency whole-body vibration (wbv) is critically discussed.	Am J Ind Med.	**	**	**	**	**	
Search Term: Low-Frequency Sound AND Health Effects										
18	2008	Carrubba S. et al.	The effects of low-frequency environmental-strength electromagnetic fields on brain electrical activity: a critical review of the literature	Electromagn Biol Med.		4				x

Search Term: Wind Power AND Noise										
List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
19	2005	Shields FD.	Low-frequency wind noise correlation in microphone arrays	J Acoust Soc Am.	**	**	**	**	**	
20	2004	Pedersen E. et al.	Perception and annoyance due to wind turbine noise--a dose-response relationship	J Acoust Soc Am.	3	5	5	2	3	
21	1998	Munro KJ. et al.	Are clinical measurements of uncomfortable loudness levels a valid indicator of real-world auditory discomfort?	Br J Audiol.		4				x
22	1992	McConnell SO. et al.	Ambient noise measurements from 100 Hz to 80 kHz in an Alaskan fjord.	J Acoust Soc Am.	**	**	**	**	**	
Search Term: Wind Turbines										
23	2008	Harding G. et al.	Wind turbines, flicker, and photosensitive epilepsy: characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them	Epilepsia.	**	**	**	**	**	

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
24	2007	Pedersen E. et al.	Wind turbine noise, annoyance and self-reported health and well-being in different living environments.	Occup Environ Med.	3	5	5	2	3	

Search Term: Wind Turbines AND Noise
ALREADY INCLUDED IN OTHER SEARCHES

Other articles found in *Noise and Health*

25	2004	Waye K.	Effects of low frequency noise on sleep.	Noise and Health	**	**	**	**	**	
26	2004	Moller H. et al.	Hearing at low and infrasonic frequencies	Noise and Health	**	**	**	**	**	
27	2004	Maschke C.	Introduction to the special issue on low frequency noise	Noise and Health	**	**	**	**	**	
28	2004	Leventhall H.	Low frequency noise and annoyance	Noise and Health	**	**	**	**	**	
29	2004	Findeis H. et al.	Disturbing effects of low frequency sound emissions and vibrations in residential buildings	Noise and Health	**	**	**	**	**	

The Potential Health Impact of Wind Turbines

Chief Medical Officer of Health (CMOH) Report
May 2010

Summary of Review

This report was prepared by the Chief Medical Officer of Health (CMOH) of Ontario in response to public health concerns about wind turbines, particularly related to noise.

Assisted by a technical working group comprised of members from the Ontario Agency for Health Protection and Promotion (OAHPP), the Ministry of Health and Long-Term Care (MOHLTC) and several Medical Officers of Health in Ontario with the support of the Council of Ontario Medical Officers of Health (COMOH), this report presents a synopsis of existing scientific evidence on the potential health impact of noise generated by wind turbines.

The review concludes that while some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects. The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct health effects, although some people may find it annoying.

Introduction

In response to public health concerns about wind turbines, the CMOH conducted a review of existing scientific evidence on the potential health impact of wind turbines in collaboration and consultation with a technical working group composed of members from the OAHPP, MOHLTC and COMOH.

A literature search was conducted to identify papers and reports (from 1970 to date) on wind turbines and health from scientific bibliographic databases, grey literature, and from a structured Internet search. Databases searched include MEDLINE, PubMed, Environmental Engineering Abstracts, Environment Complete, INSPEC, Scholars Portal and Scopus. Information was also gathered through discussions with relevant government agencies, including the Ministry of the Environment and the Ministry of Energy and Infrastructure and with input provided by individuals and other organizations such as Wind Concerns Ontario.

In general, published papers in peer-reviewed scientific journals, and reviews by recognized health authorities such as the World Health Organization (WHO) carry more weight in the assessment of health risks than case studies and anecdotal reports.

The review and consultation with the Council of Ontario Medical Officers of Health focused on the following questions:

- What scientific evidence is available on the potential health impacts of wind turbines?
- What is the relationship between wind turbine noise and health?
- What is the relationship between low frequency sound, infrasound and health?
- How is exposure to wind turbine noise assessed?
- Are Ontario wind turbine setbacks protective from potential wind turbine health and safety hazards?
- What consultation process with the community is required before wind farms are constructed?
- Are there data gaps or research needs?

The following summarizes the findings of the review and consultation.

2

Wind Turbines and Health

2.1 Overview

A list of the materials reviewed is found in Appendix 1. It includes research studies, review articles, reports, presentations, and websites.

Technical terms used in this report are defined in a Glossary (Page 11).

The main research data available to date on wind turbines and health include:

- Four cross-sectional studies, published in scientific journals, which investigated the relationships between exposure to wind turbine noise and annoyance in large samples of people (351 to 1,948) living in Europe near wind turbines (see section 2.2).
- Published case studies of ten families with a total of 38 affected people living near wind turbines in several countries (Canada, UK, Ireland, Italy and USA) (Pierpont 2009). However, these cases are not found in scientific journals. A range of symptoms including dizziness, headaches, and sleep disturbance, were reported by these people. The researcher (Pierpont) suggested that the symptoms were related to wind turbine noise, particularly low frequency sounds and infrasound, but did not investigate the relationships between noise and symptoms. It should be noted that no conclusions on the health impact of wind turbines can be drawn from Pierpont's work due to methodological limitations including small sample size, lack of exposure data, lack of controls and selection bias.
- Research on the potential health and safety hazards of wind turbine shadow flicker, electromagnetic fields (EMFs), ice throw and ice shed, and structural hazards (see section 2.3).

A synthesis of the research available on the potential health impacts of exposure to noise and physical hazards from wind turbines on nearby residents is found in sections 2.2 and 2.3, including research on low frequency sound and infrasound. This is followed by information on wind turbine regulation in Ontario (section 3.0), and our conclusions (section 4.0).

2.2. Sound and Noise

Sound is characterized by its sound pressure level (loudness) and frequency (pitch), which are measured in standard units known as decibel (dB) and Hertz (Hz), respectively. The normal human ear perceives sounds at frequencies ranging from 20Hz to 20,000 Hz. Frequencies below 200 Hz are commonly referred to as “low frequency sound” and those below 20Hz as “infrasound,” but the boundary between them is not rigid. There is variation between people in their ability to perceive sound. Although generally considered inaudible, infrasound at high-enough sound pressure levels can be audible to some people. Noise is defined as an unwanted sound (Rogers et al. 2006, Leventhall 2003).

Wind turbines generate sound through mechanical and aerodynamic routes. The sound level depends on various factors including design and wind speed. Current generation upwind model turbines are quieter than older downwind models. The dominant sound source from modern wind turbines is aerodynamic, produced by the rotation of the turbine blades through air. The aerodynamic noise is present at all frequencies, from infrasound to low frequency to the normal audible range, producing the characteristic “swishing” sound (Leventhall 2006, Colby et al. 2009).

Environmental sound pressure levels are most commonly measured using an A-weighted scale. This scale gives less weight to very low and very high frequency components that is similar to the way the human ear perceives sound. Sound levels around wind turbines are usually predicted by modelling, rather than assessed by actual measurements.

The impact of sound on health is directly related to its pressure level. High sound pressure levels (>75dB) could result in hearing impairment depending on the duration of exposure and sensitivity of the individual. Current requirements for wind turbine setbacks in Ontario are intended to limit noise at the nearest residence to 40 dB (see section 3). This is a sound level comparable to indoor background sound. This noise limit is consistent with the night-time noise guideline of 40 dB that the World Health Organization (WHO) Europe recommends for the protection of public health from community noise. According to the WHO, this guideline is below the level at which effects on sleep and health occurs. However, it is above the level at which complaints may occur (WHO 2009).

Available scientific data indicate that sound levels associated with wind turbines at common residential setbacks are not sufficient to damage hearing or to cause other direct adverse health effects, but some people may still find the sound annoying.

Studies in Sweden and the Netherlands (Pedersen et al. 2009, Pedersen and Waye 2008, Pedersen and Waye 2007, Pedersen and Waye 2004) have found direct relationships between modelled sound pressure level and self-reported perception of sound and annoyance. The association between sound pressure level and sound perception was stronger than that with annoyance. The sound was annoying only to a small percentage of the exposed people; approximately 4 to 10 per cent were very annoyed at sound levels between 35 and 45dBA. Annoyance was strongly correlated with individual perceptions of wind turbines. Negative attitudes, such as an aversion to the visual impact of wind turbines on the landscape, were associated with increased annoyance, while positive attitudes, such as direct economic benefit from wind turbines, were associated with decreased annoyance. Wind turbine noise was perceived as more annoying than transportation or industrial noise at comparable levels, possibly due to its swishing quality, changes throughout a 24 hour period, and lack of night-time abatement.

2.2.1 Low Frequency Sound, Infrasound and Vibration

Concerns have been raised about human exposure to “low frequency sound” and “infrasound” (see section 2.2 for definitions) from wind turbines. There is no scientific evidence, however, to indicate that low frequency sound generated from wind turbines causes adverse health effects.

Low frequency sound and infrasound are everywhere in the environment. They are emitted from natural sources (e.g., wind, rivers) and from artificial sources including road traffic, aircraft, and ventilation systems. The most common source of infrasound is vehicles. Under many conditions, low frequency sound below 40Hz from wind turbines cannot be distinguished from environmental background noise from the wind itself (Leventhall 2006, Colby et al 2009).

Low frequency sound from environmental sources can produce annoyance in sensitive people, and infrasound at high sound pressure levels, above the threshold for human hearing, can cause severe ear pain. There is no evidence of adverse health effects from infrasound below the sound pressure level of 90dB (Leventhall 2003 and 2006).

Studies conducted to assess wind turbine noise indicate that infrasound and low frequency sounds from modern wind turbines are well below the level where known health effects occur, typically at 50 to 70dB.

A small increase in sound level at low frequency can result in a large increase in perceived loudness. This may be difficult to ignore, even at relatively low sound pressures, increasing the potential for annoyance (Jakobsen 2005, Leventhall 2006).

A Portuguese research group (Alves-Pereira and Castelo Branco 2007) has proposed that excessive long-term exposure to vibration from high levels of low frequency sound and infrasound can cause whole body system pathology (vibro-acoustic disease). This finding has not been recognized by the international medical and scientific community. This research group also hypothesized that a family living near wind turbines will develop vibro-acoustic disease from exposure to low frequency sound, but has not provided evidence to support this (Alves-Pereira and Castelo Branco 2007).

2.2.2 Sound Exposure Assessment

Little information is available on actual measurements of sound levels generated from wind turbines and other environmental sources. Since there is no widely accepted protocol for the measurement of noise from wind turbines, current regulatory requirements are based on modelling (see section 3.0).

2.3 Other Potential Health Hazards of Wind Turbines

The potential health impacts of electromagnetic fields (EMFs), shadow flicker, ice throw and ice shed, and structural hazards of wind turbines have been reviewed in two reports (Chatham-Kent Public Health Unit 2008; Rideout et al 2010). The following summarizes the findings from these reviews.

- **EMFs**
Wind turbines are not considered a significant source of EMF exposure since emissions levels around wind farms are low.
- **Shadow Flicker**
Shadow flicker occurs when the blades of a turbine rotate in sunny conditions, casting moving shadows on the ground that result in alternating changes in light intensity appearing to flick on and off. About 3 per cent of people with epilepsy are photosensitive, generally to flicker frequencies between 5-30Hz. Most industrial turbines rotate at a speed below these flicker frequencies.
- **Ice Throw and Ice Shed**
Depending on weather conditions, ice may form on wind turbines and may be thrown or break loose and fall to the ground. Ice throw launched far from the turbine may pose a significant hazard. Ice that sheds from stationary components presents a potential risk to service personnel near the wind farm. Sizable ice fragments have been reported to be found within 100 metres of the wind turbine. Turbines can be stopped during icy conditions to minimize the risk.
- **Structural hazards**
The maximum reported throw distance in documented turbine blade failure is 150 metres for an entire blade, and 500 metres for a blade fragment. Risks of turbine blade failure reported in a Dutch handbook range from one in 2,400 to one in 20,000 turbines per year (Braam et al 2005). Injuries and fatalities associated with wind turbines have been reported, mostly during construction and maintenance related activities.

Wind Turbine Regulation in Ontario

The Ministry of the Environment regulates wind turbines in Ontario. A new regulation for renewable energy projects came into effect on September 24, 2009. The requirements include minimum setbacks and community consultations.

3.1 Setbacks

Provincial setbacks were established to protect Ontarians from potential health and safety hazards of wind turbines including noise and structural hazards.

The minimum setback for a wind turbine is 550 metres from a receptor. The setbacks rise with the number of turbines and the sound level rating of the selected turbines. For example, a wind project with five turbines, each with a sound power level of 107dB, must have its turbines setback at a minimum 950 metres from the nearest receptor.

These setbacks are based on modelling of sound produced by wind turbines and are intended to limit sound at the nearest residence to no more than 40 dB. This limit is consistent with limits used to control noise from other environmental sources. It is also consistent with the night-time noise guideline of 40 dB that the World Health Organization (WHO) Europe recommends for the protection of public health from community noise. According to the WHO, this guideline is below the level at which effects on sleep and health occurs. However, it is above the level at which complaints may occur (WHO 2009).

Ontario used the most conservative sound modelling available nationally and internationally, which is supported by experiences in the province and in other jurisdictions (MOE 2009). As yet, a measurement protocol to verify compliance with the modelled limits in the field has not been developed. The Ministry of the Environment has recently hired independent consultants to develop a procedure for measuring audible sound from wind turbines and also to review low frequency sound impacts from wind turbines, and to develop recommendations regarding low frequency sound.

Ontario setback distances for wind turbine noise control also take into account potential risk of injury from ice throw and structural failure of wind turbines. The risk of injury is minimized with setbacks of 200 to 500 metres.

3.2 Community Consultation

The Ministry of the Environment requires applicants for wind turbine projects to provide written notice to all assessed land owners within 120 metres of the project location at a preliminary stage of the project planning. Applicants must also post a notice on at least two separate days in a local newspaper. As well, applicants are required to notify local municipalities and any Aboriginal community that may have a constitutionally protected right or interest that could be impacted by the project.

Before submitting an application to the Ministry of the Environment, the applicant is also required to hold a minimum of two community consultation meetings to discuss the project and its potential local impact. To ensure informed consultation, any required studies must be made available for public review 60 days prior to the date of the final community meeting. Following these meetings the applicant is required to submit as part of their application a Consultation Report that describes the comments received and how these comments were considered in the proposal.

The applicant must also consult directly with local municipalities prior to applying for a Renewable Energy Approval on specific matters related to municipal lands, infrastructure, and services. The Ministry of the Environment has developed a template, which the applicant is required to use to document project-specific matters raised by the municipality. This must be submitted to the ministry as part of the application. The focus of this consultation is to ensure important local service and infrastructure concerns are considered in the project.

For small wind projects (under 50 kW) the public meeting requirements above are not applicable due to their limited potential impacts.

4

Conclusions

The following are the main conclusions of the review and consultation on the health impacts of wind turbines:

- While some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects.
- The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct adverse health effects. However, some people might find it annoying. It has been suggested that annoyance may be a reaction to the characteristic “swishing” or fluctuating nature of wind turbine sound rather than to the intensity of sound.
- Low frequency sound and infrasound from current generation upwind model turbines are well below the pressure sound levels at which known health effects occur. Further, there is no scientific evidence to date that vibration from low frequency wind turbine noise causes adverse health effects.
- Community engagement at the outset of planning for wind turbines is important and may alleviate health concerns about wind farms.
- Concerns about fairness and equity may also influence attitudes towards wind farms and allegations about effects on health. These factors deserve greater attention in future developments.

The review also identified that sound measurements at residential areas around wind turbines and comparisons with sound levels around other rural and urban areas, to assess actual ambient noise levels prevalent in Ontario, is a key data gap that could be addressed. An assessment of noise levels around wind power developments and other residential environments, including monitoring for sound level compliance, is an important prerequisite to making an informed decision on whether epidemiological studies looking at health outcomes will be useful.

Glossary

A-weighted decibels (dBA)

The sound pressure level in decibels as measured on a sound level meter using an A-weighted filter. The A-weighted filter de-emphasizes the very low and very high frequencies of the sound in a manner similar to the frequency response of the human ear.

Decibel (dB)

Unit of measurement of the loudness (intensity) of sound. Loudness of normal adult human voice is about 60-70 dB at three feet. The decibel scale is a logarithmic scale and it increases/decreases by a factor of 10 from one scale increment to the next adjacent one.

Downwind model turbines

Downwind model turbines have the blades of the rotor located behind the supporting tower structure, facing away from the wind. The supporting tower structure blocks some of the wind that blows towards the blades.

Electromagnetic fields (EMFs)

Electromagnetic fields are a combination of invisible electric and magnetic fields. They occur both naturally (light is a natural form of EMF) and as a result of human activity. Nearly all electrical and electronic devices emit some type of EMF.

Grey literature

Information produced by all levels of government, academics, business and industry in electronic and print formats not controlled by commercial publishing, i.e., where publishing is not the primary activity of the producing body.

Hertz (Hz)

A unit of measurement of frequency; the number of cycles per second of a periodic waveform.

Infrasound

Commonly refers to sound at frequencies below 20Hz. Although generally considered inaudible, infrasound at high-enough sound pressure levels can be audible to some people.

Low frequency sound

Commonly refers to sound at frequencies between 20 and 200 Hz.

Noise

Noise is an unwanted sound.

Shadow Flicker

Shadow flicker is a result of the sun casting intermittent shadows from the rotating blades of a wind turbine onto a sensitive receptor such as a window in a building. The flicker is due to alternating light intensity between the direct beam of sunlight and the shadow from the turbine blades.

Sound

Sound is wave-like variations in air pressure that occur at frequencies that can be audible. It is characterized by its loudness (sound pressure level) and pitch (frequency), which are measured in standard units known as decibel (dB) and Hertz (Hz), respectively. The normal human ear perceives sounds at frequencies ranging from 20Hz to 20,000 Hz.

Upwind model turbines

Upwind model turbines have the blades of the rotor located in front of the supporting tower structure, similar to how a propeller is at the front of an airplane. Upwind turbines are a modern design and are quieter than the older downwind models.

Wind turbine

Wind turbines are large towers with rotating blades that use wind to generate electricity.

Appendix 1: List of Documents on Wind Turbines

Journal Articles and Books

- Braam HGJ, et al. Handboek risicozonering windturbines. Netherlands: SenterNovem; 2005.
- Jakobsen J. Infrasound emission from wind turbines. *J Low Freq Noise Vib Active Contr.* 2005;24(3):145-155.
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Wind Turbines and Health

A Rapid Review of the Evidence

July 2010

Wind Turbines and Health – A Rapid Review of the Evidence

The purpose of this paper is to present findings from a rapid review of the evidence from current literature on the issue of wind turbines and potential impacts on human health. In particular the paper seeks to ascertain if the following statement can be supported by the evidence: *There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines.* This statement is supported by the 2009 expert review commissioned by the American and Canadian Wind Energy Associations (Colby et al. 2009).

Context

In Australia, since the legislation of the *Renewable Energy (Electricity) Act* in 2000, wind power has been gaining prominence as a viable sustainable alternative to more traditional forms of energy production. Studies have found that there is increasing population demand for 'green' energy and that people are willing to pay a premium for renewable energy (Chatham-Kent Public Health Unit, 2008; Pedersen & Persson Waye, 2007). However as with any shift in technology, the emergence of wind farms is not without controversy.

There are two opposing viewpoints regarding wind turbines and their potential effect on human health. It is important to note that these views are frequently presented by groups or people with vested interests. For example, wind energy associations purport that there is no evidence linking wind turbines to human health concerns. Conversely, individuals or groups who oppose the development of wind farms contend that wind turbines can adversely impact the health of individuals living in proximity to wind farms.

Concerns regarding the adverse health impacts of wind turbines focus on the effects of infrasound, noise, electromagnetic interference, shadow flicker and blade glint produced by wind turbines. Does the evidence support these concerns?

Sound and Noise from Wind Turbines

Sound is composed of frequency expressed as hertz (Hz) and pressure expressed as decibels (dB). In terms of frequency sound can be categorised as audible and inaudible. Infrasound is commonly defined as sound which is inaudible to the human ear (below 16 Hz). Despite this commonly used definition, infrasound can be audible (EPHC, 2009). There is often confusion regarding the boundary between infrasound and low frequency noise (Leventhall, 2006). Human sensitivity to sound, especially to low frequency sound, is variable and people will exhibit variable levels of tolerance to different frequencies (Minnesota Department of Health, 2009).

Noise can be defined as any undesirable or unwanted sound. The perception of the noise is also influenced by the attitude of the hearer towards the sound source. This is sometimes called the nocebo effect, which is the opposite of the better known placebo effect. If people have been preconditioned to hold negative opinions about a noise source, they are more likely to be affected by it (AusWEA, 2004).

Wind turbines produce noise that can be classified into the following categories:

1. Mechanical noise which is produced from the motor or gearbox; if functioning correctly, mechanical noise from modern wind turbines should not be an issue.
2. Aerodynamic noise which is produced by wind passing over the blade of the wind turbine (Minnesota Department of Health, 2009).

As well as the general audible range of sound emissions, wind turbines also produce noise that includes a range of Special Audible Characteristics (SACs) such as amplitude modulation, impulsivity, low frequency noise and tonality (EPHC, 2009).

Table 1 compares the noise produced by a ten turbine wind farm compared to noise levels from some selected activities.

Activity	Sound pressure level (dBA) ¹
Jet aircraft at 250m	105
Noise in a busy office	60
Car travelling at 64kph at 100m	55
Wind farm (10 turbines) at 350m	35-45
Quiet bedroom	35
Background noise in rural area at night	20-40

Table 1: Noise levels compared to ten turbine wind farm (SDC, 2005).

Macintosh and Downie (2006) conclude that based on these figures “noise pollution generated by wind turbines is negligible”.

One of the most common assertions regarding potential adverse noise impacts of wind turbines is concerned with low frequency noise and infrasound. It should be noted that infrasound is constantly present in the environment and is caused by various sources such as ambient air turbulence, ventilation units, ocean waves, distant explosions, volcanic eruptions, traffic, aircraft and other machinery (Rogers, Manwell & Wright, 2006). In relation to wind turbines, Leventhall (2006) concludes that there is insignificant infrasound generated by wind turbines and that there is normally little low frequency noise. A survey of all known published results of infrasound from wind turbines found that wind turbines of contemporary design, where rotor blades are in front of the tower, produce very low levels of infrasound (Jakobsen, 2005). Another recent report concludes that wind farm noise does not have significant low-frequency or infrasound components (Ministry of the Environment, 2007). As discussed in further detail below the principal human response to audible infrasound is annoyance (Rogers, 2006).

Effects of Noise from Wind Turbines on Human Health

The health and well-being effects of noise on people can be classified into three broad categories:

¹ The “A” represents a weighting of measured sound to mimic that discernable by the human ear, which does not perceive sound at low and high frequencies to be as loud as mid range frequencies (AusWEA, nd, a).

1. subjective effects including annoyance, nuisance and dissatisfaction;
2. interference with activities such as speech, sleep and learning; and
3. physiological effects such as anxiety, tinnitus or hearing loss (Rogers, Manwell & Wright, 2006).

Several commentators argue that noise from wind turbines only produces effects in the first two categories (Rogers, 2006; Pedersen & Persson Waye, 2007).

Various studies of wind turbine effects on health have concentrated on the self-reported perception of annoyance. There are difficulties with measuring and quantifying subjective effects of noise such as annoyance. According to the World Health Organization (WHO) (1999) annoyance is an adverse health effect, though this is not universally accepted. Kalveram proposes that annoyance is not a direct health effect but an indication that a person's capacity to cope is under threat. The person has to resolve the threat or their coping capacity is undermined, leading to stress related health effects (Kalveram 2000). Some people are very annoyed at quite low levels of noise, whilst others are not annoyed by high levels.

It has been suggested that if people are worried about their health they may become anxious, causing stress related illnesses. These are genuine health effects arising from their worry, which arises from the wind turbine, even though the turbine may not objectively be a risk to health (Chapman 2010). The measurement of health effects attributable to wind turbines is therefore very complex.

One study of wind turbine noise and annoyance found that no adverse health effects other than annoyance could be directly correlated with noise from wind turbines. The authors concluded that reported sleep difficulties, as well as feelings of uneasiness, associated with noise annoyance could be an effect of the exposure to noise, although it could just as well be that respondents with sleeping difficulties more easily appraised the noise as annoying (Pedersen & Persson Waye, 2007).

Many factors can influence the way noise from wind turbines is perceived. The aforementioned study also found that being able to see wind turbines from one's residence increased not just the odds of perceiving the sound, but also the odds of being annoyed, suggesting a multimodal effect of the audible and visual exposure from the same source leading to an enhancement of the negative appraisal of the noise by the visual stimuli (Pedersen & Persson Waye, 2007). Another study of residents living in the vicinity of wind farms in the Netherlands found that annoyance was strongly correlated with a negative attitude toward the visual impact of wind turbines on the landscape. The study also concluded that people who benefit economically from wind turbines were less likely to report noise annoyance, despite exposure to similar sound levels as those people who were not economically benefiting (Pedersen et al, 2009).

In addition to audible noise, concerns have been raised about infrasound from wind farms and health effects. It has been noted that the effects of low frequency infrasound (less than 20Hz) on humans are not well understood (NRC, 2007). However, as discussed above, several authors have suggested that low level frequency noise or infrasound emitted by wind turbines is minimal and of no consequence (Leventhall, 2006; Jakobsen, 2005). Further, numerous reports have concluded that there is no evidence of health effects arising from infrasound or low frequency noise

generated by wind turbines (DTI, 2006; CanWEA, 2009; Chatham-Kent Public Health Unit, 2008; WHO, 2004; EPHC, 2009; HGC Engineering, 2007). In summary:

- 'There is no reliable evidence that infrasounds below the hearing threshold produce physiological or psychological effects' (Berglund & Lindvall 1995).
- Infrasound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to the health of a wind farm neighbour (DTI, 2006).
- Findings clearly show that there is no peer-reviewed scientific evidence indicating that wind turbines have an adverse impact on human health (CanWEA, 2009).
- Sound from wind turbines does not pose a risk of hearing loss or any other adverse health effects in humans. Subaudible, low frequency sounds and infrasound from wind turbines do not present a risk to human health (Colby, et al 2009).
- The Chatham-Kent Public Health Unit (Ontario, Canada) reviewed the current literature regarding the known health impacts of wind turbines in order to make an evidence-based decision. Their report concluded that current evidence failed to demonstrate a health concern associated with wind turbines. 'In summary, as long as the Ministry of Environment Guidelines for location criteria of wind farms are followed ... there will be negligible adverse health impacts on Chatham-Kent citizens. Although opposition to wind farms on aesthetic grounds is a legitimate point of view, opposition to wind farms on the basis of potential adverse health consequences is not justified by the evidence' (Chatham-Kent Public Health Unit, 2008).
- Wind energy is associated with fewer health effects than other forms of traditional energy generation and in fact will have positive health benefits (WHO, 2004).
- 'There are, at present, very few published and scientifically-validated cases of an SACs of wind farm noise emission being problematic ... the extent of reliable published material does not, at this stage, warrant inclusion of SACs ... into the noise impact assessment planning stage (EPHC, 2009).
- While a great deal of discussion about infrasound in connection with wind turbine generators exists in the media there is no verifiable evidence for infrasound and production by modern turbines (HGC Engineering, 2007).

The opposing view is that noise from wind turbines produces a cluster of symptoms which has been termed Wind Turbine Syndrome (WTS). The main proponent of WTS is a US based paediatrician, Dr Pierpont, who has released a book 'Wind Turbine Syndrome: A report on a Natural Experiment, presents case studies explaining WTS symptoms in relation to infrasound and low frequency noise. Dr Pierpont's assertions are yet to be published in a peer-reviewed journal, and have been heavily criticised by

acoustic specialists. Based on current evidence, it can be concluded that wind turbines do not pose a threat to health if planning guidelines are followed.

Shadow Flicker and Blade Glint

Shadow flicker occurs when the sun is located behind a wind turbine casting a shadow that appears to flick on and off as the wind turbine blades rotate (Chatham-Kent Public health Unit, 2008). It is possible to use modelling software to model shadow flicker before the finalisation of a wind farm layout and siting.

Blade glint occurs when the surface of wind turbine blades reflect the sun's light and has the potential to annoy people (EPHC, 2009).

Effects of Shadow Flicker and Blade Glint on Human Health

Shadow flicker from wind turbines that interrupts sunlight at flash frequencies greater than 3Hz has the potential to provoke photosensitive seizures (Harding, Harding & Wilkins, 2008). As such it is recommended that to circumvent potential health effects of shadow flicker wind turbines should only be installed if flicker frequency remains below 2.5 Hz under all conditions (Harding, Harding & Wilkins, 2008).

According to the EPHC (2009) there is negligible risk of seizures being caused by modern wind turbines for the following reasons:

- less than 0.5% of the population are subject to epilepsy at any one time, and of these, approximately 5% are susceptible to strobing light;
- Most commonly (96% of the time), those that are susceptible to strobe lighting are affected by frequencies in excess of 8 Hz and the remainder are affected by frequencies in excess of 2.5 Hz. Conventional horizontal axis wind turbines cause shadow flicker at frequencies of around 1 Hz or less;
- alignment of three or more conventional horizontal axis wind turbines could cause shadow flicker frequencies in excess of 2.5 Hz; however, this would require a particularly unlikely turbine configuration.

In summary, the evidence on shadow flicker does not support a health concern (Chatham-Kent Public Health Unit, 2008) as the chance of conventional horizontal axis wind turbines causing an epileptic seizure for an individual experiencing shadow flicker is less than 1 in 10 million (EPHC, 2009). As with noise, the main impact associated with shadow flicker from wind turbines is annoyance.

In regards to blade glint, manufacturers of all major wind turbine blades coat their blades with a low reflectivity treatment which prevents reflective glint from the surface of the blade. According to the Environment Protection and Heritage Council (EPHC) the risk of blade glint from modern wind turbines is considered to be very low (EPHC, 2009).

Electromagnetic Radiation and Interference

Electromagnetic radiation (EMR) is a wavelike pattern of electric and magnetic energy moving together. Types of EMR include X-rays, ultraviolet, visible light, infrared and radio waves (AusWEA, nd. b).

Electromagnetic interference (EMI) from wind turbines may affect electromagnetic or radiocommunication signals including broadcast radio and television, mobile phones and radar (EPHC, 2009).

As high and exposed sites are best from a wind resource perspective, it is not unusual for any of a range of telecommunications installations, radio and television masts, mobile phone base stations or emergency service radio masts to be located nearby. Care must be taken to ensure that wind turbines do not passively interfere with these facilities by directly obstructing, reflecting or refracting their radio frequency EMR signals.

Effects of Electromagnetic Radiation and Interference from Wind Turbines on Human Health

Electromagnetic Fields (EMF) emanate from any wire carrying electricity and Australians are routinely exposed to these fields in their everyday lives. The electromagnetic fields produced by the generation and export of electricity from a wind farm do not pose a threat to public health (Windrush Energy 2004). The closeness of the electrical cables between wind turbine generators to each other, and shielding with metal armour effectively eliminate any EMF (AusWEA, nd. b).

Measures to Mitigate Potential Impacts of Wind Turbines

As with the introduction of any new technology, some communities are against wind farms being located in their area. Some factors which may increase community concern include coerced or unequal exposure, industrial, exotic and/or memorable nature of the turbine, dreaded, unknown or catastrophic consequences, substantial media attention, potential for collective action and a process which is unresponsive to the community. Voluntary exposure, for example choosing to house the turbine on community land, reduces concern (Adapted by Professor Chapman from Covello et al. methodology 1986).

One review of wind turbines and noise recommends that best practice guidelines such as those identifying potential receptors of turbine noise, following established setbacks and dispelling rumours regarding infrasound which have not been supported by research, are followed in order to mitigate any potential noise issues associated with wind turbines (Howe, 2007).

Sustainable Energy Authority Victoria (2003) also recommend that complying with standards relating to turbine design and manufacturing, site evaluation and final siting of wind turbines will minimise any potential impacts on the surrounding area.

The recently released Draft National Wind Farm Development Guidelines (EPHC, 2009) include detailed methodologies at different stages of the planning and development process to assess such issues as noise and shadow flicker to mitigate any potential impact. Such processes include a range of measures such as high-level risk assessment, data collection, impact assessment, detailed technical studies and public consultation.

Therefore if planning guidelines are followed and communities are consulted with in a meaningful way, resistance to wind farms is likely to be reduced and annoyance and related health effects avoided.

Conclusion

The health effects of many forms of renewable energy generation, such as wind farms, have not been assessed to the same extent as those from traditional sources. However, renewable energy generation is associated with few adverse health effects compared with the well documented health burdens of polluting forms of electricity generation (Markandya & Wilkinson, 2007).

This review of the available evidence, including journal articles, surveys, literature reviews and government reports, supports the statement that: *There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines.*

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**National Health and Medical Research Council
Submission to
the Senate Standing Committee for Community Affairs**

Inquiry into the Social and Economic Impact of Rural Wind Farm

1. The National Health and Medical Research Council (NHMRC) thanks the Senate Standing Committee for Community Affairs for the opportunity to provide a written submission to this inquiry.
2. NHMRC would be pleased to answer any further questions in writing or by teleconference if required by the Committee.

Introduction

3. The NHMRC is the Australian Government body that funds health and medical research, under the *National Health and Medical Research Council Act 1922* (the NHMRC Act).
4. The NHMRC also has a statutory responsibility to inquire into, issue guidelines on, and advise the community, on matters relating (inter alia) to:
 - the improvement of health,
 - the prevention, treatment and diagnosis of disease and
 - public health research (section 7 of the NHMRC Act).
5. NHMRC at various times releases public statements on topical health issues. It uses a range of communication avenues to issue health advice, including notices placed on its website, public statements, advice to the responsible Minister and/or NHMRC developed publications.
6. NHMRC follows rigorous, international best-practice standards for evidence used in its research translation work¹. As well, NHMRC has strict guidelines on conflicts of interest covering cases where there may be perceived or real interests in research such as commercial interests.
7. It is important for the protection of the Australian public that NHMRC base its advice solely on the best available, unbiased, current scientific evidence.

¹ NHMRC (2000) *How to put evidence into practice: Implementation and dissemination strategies*.

Background to the NHMRC statement on wind turbines and health

8. The NHMRC Council² raised the possible adverse effects of wind turbines as a topic meriting further investigation in October 2009, because of growing public concern, the expanding use of wind turbines and the lack of evidence based advice available to the public.
9. A review of the available scientific literature was submitted to Council's December 2009 meeting. Based on this, a draft public statement was prepared and submitted to Council in May 2010 and issued in July 2010. The publications were reviewed by three expert international and local peer reviewers before being issued.
10. The review, *Wind Turbines and Health: A Rapid Review of the Evidence*, and the summary of its findings, *NHMRC Public Statement: Wind Turbines and Health (Attachments A and B)* are available on the NHMRC website <http://www.nhmrc.gov.au/publications/synopses/new0048.htm>.
11. These publications were based on the scientific literature to provide evidence based information to members of the public, Government planning bodies and health professionals.
12. The review considered research on a number of potential health impacts, including of noise, infrasound (sound which is inaudible to the human ear), electromagnetic interference, shadow flicker and blade glint.

Comment

13. The NHMRC review found that there was no published scientific evidence to positively link wind turbines with adverse health effects.
14. NHMRC is aware of many anecdotes of people living near wind turbines experiencing health effects. These anecdotes, however, need further scientific investigation.
15. The NHMRC statement therefore suggested that "people who believe that they experiencing any health problems should consult their GP promptly". In doing so, they will contribute to the body of knowledge to inform future health and medical research on this issue.
16. The Public Statement concluded that the evidence was limited and recommended "that authorities take a precautionary approach and continue to monitor new research outcomes".

² Membership of NHMRC Council includes the Commonwealth Medical Officer and State and Territory Chief Health Officers.

17. Accordingly, NHMRC has made a commitment, since the documents were published, to continue to review the scientific information and update its statement.

Planned new NHMRC work on wind turbines and health

18. The evidence base for the public statement is now nearly two years old.

19. NHMRC has begun updating its review of the published scientific literature.

20. To ensure that the review of literature draws on the range of experience that has developed over the past two years, NHMRC will also consult international experts from countries with substantial experience with wind turbines.

21. NHMRC will ensure that its consultation and review processes take account of the literature and information needs of the community.

22. The updated literature review and outcomes of the workshop will inform NHMRC in revision of the *Rapid Review* and *Summary of Findings*. The timing of completion of this work will depend on the outcomes of these two activities.

23. As outlined at paragraph 9 above, NHMRC will continue to develop its advice based on evidence based scientific literature.

Professor Warwick Anderson
Chief Executive Officer
29 March 2011

Wind Turbine Sound and Health Effects

An Expert Panel Review

Executive Summary

Prepared by (in alphabetical order):

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David M. Lipscomb, Ph.D.

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Prepared for:

American Wind Energy Association

and

Canadian Wind Energy Association

December 2009

Executive Summary

People have been harnessing the power of the wind for more than 5,000 years. Initially used widely for farm irrigation and millworks, today's modern wind turbines produce electricity in more than 70 countries. As of the end of 2008, there were approximately 120,800 megawatts of wind energy capacity installed around the world (Global Wind Energy Council, 2009).

Wind energy enjoys considerable public support, but it also has its detractors, who have publicized their concerns that the sounds emitted from wind turbines cause adverse health consequences.

In response to those concerns, the American and Canadian Wind Energy Associations (AWEA and CanWEA) established a scientific advisory panel in early 2009 to conduct a review of current literature available on the issue of perceived health effects of wind turbines. This multidisciplinary panel is comprised of medical doctors, audiologists, and acoustical professionals from the United States, Canada, Denmark, and the United Kingdom. The objective of the panel was to provide an authoritative reference document for legislators, regulators, and anyone who wants to make sense of the conflicting information about wind turbine sound.

The panel undertook extensive review, analysis, and discussion of the large body of peer-reviewed literature on sound and health effects in general, and on sound produced by wind turbines. Each panel member contributed a unique expertise in audiology, acoustics, otolaryngology, occupational/ environmental medicine, or public health. With a diversity of perspectives represented, the panel assessed the plausible biological effects of exposure to wind turbine sound.

Following review, analysis, and discussion of current knowledge, the panel reached consensus on the following conclusions:

- There is no evidence that the audible or sub-audible sounds emitted by wind turbines have any direct adverse physiological effects.
- The ground-borne vibrations from wind turbines are too weak to be detected by, or to affect, humans.
- The sounds emitted by wind turbines are not unique. There is no reason to believe, based on the levels and frequencies of the sounds and the panel's experience with sound exposures in occupational settings, that the sounds from wind turbines could plausibly have direct adverse health consequences.

Conclusions

Many countries have turned to wind energy as a key strategy to generate power in an environmentally clean manner. Wind energy enjoys considerable public support, but it has its detractors, who have publicized their concerns that the sounds emitted from wind turbines cause adverse health consequences.

The objective of the panel was to develop an authoritative reference document for the use of legislators, regulators, and citizens simply wanting to make sense of the conflicting information about wind turbine sound. To this end, the panel undertook extensive review, analysis, and discussion of the peer-reviewed literature on wind turbine sound and possible health effects. The varied professional backgrounds of panel members (audiology, acoustics, otolaryngology, occupational and environmental medicine, and public health) were highly advantageous in creating a diversity of informed perspectives. Participants were able to examine issues surrounding health effects and discuss plausible biological effects with considerable combined expertise.

Following review, analysis, and discussion, the panel reached agreement on three key points:

- There is nothing unique about the sounds and vibrations emitted by wind turbines.
- The body of accumulated knowledge about sound and health is substantial.
- The body of accumulated knowledge provides no evidence that the audible or subaudible sounds emitted by wind turbines have any direct adverse physiological effects.

The panel appreciated the complexities involved in the varied human reactions to sound, particularly sounds that modulate in intensity or frequency. Most complaints about wind turbine sound relate to the aerodynamic sound component (the swish sound) produced by the turbine blades. The sound levels are similar to the ambient noise levels in urban environments. A small minority of those exposed report annoyance and stress associated with noise perception.

This report summarizes a number of physical and psychological variables that may influence adverse reactions. In particular, the panel considered “wind turbine syndrome” and vibroacoustic disease, which have been claimed as causes of adverse health effects. The evidence indicates that “wind turbine syndrome” is based on misinterpretation of physiologic data and that the features of the so-called syndrome are merely a subset of annoyance reactions. The evidence for vibroacoustic disease (tissue inflammation and fibrosis associated with sound exposure) is extremely dubious at levels of sound associated with wind turbines.

The panel also considered the quality of epidemiologic evidence required to prove harm. In epidemiology, initial case reports and uncontrolled observations of disease associations

need to be confirmed through controlled studies with case-control or cohort methodology before they can be accepted as reflective of casual connections between wind turbine sound and health effects. In the area of wind turbine health effects, no case-control or cohort studies have been conducted as of this date. Accordingly, allegations of adverse health effects from wind turbines are as yet unproven. Panel members agree that the number and uncontrolled nature of existing case reports of adverse health effects alleged to be associated with wind turbines are insufficient to advocate for funding further studies.

In conclusion:

1. Sound from wind turbines does not pose a risk of hearing loss or any other adverse health effect in humans.
2. Subaudible, low frequency sound and infrasound from wind turbines do not present a risk to human health.
3. Some people may be annoyed at the presence of sound from wind turbines. Annoyance is not a pathological entity.
4. A major cause of concern about wind turbine sound is its fluctuating nature. Some may find this sound annoying, a reaction that depends primarily on personal characteristics as opposed to the intensity of the sound level.

Expert Panel Members

Members of the expert panel are listed below. Biographies of each member are provided following the list.

Expert Panel Members

W. David Colby, M.D.

Chatham-Kent Medical Officer of Health (Acting)
Associate Professor, Schulich School of Medicine & Dentistry, University of Western Ontario

Robert Dobie, M.D.

Clinical Professor, University of Texas, San Antonio
Clinical Professor, University of California, Davis

Geoff Leventhall, Ph.D.

Consultant in Noise Vibration and Acoustics, UK

David M. Lipscomb, Ph.D.

President, Correct Service, Inc.

Robert J. McCunney, M.D.

Research Scientist, Massachusetts Institute of Technology Department of Biological Engineering,
Staff Physician, Massachusetts General Hospital Pulmonary Division; Harvard Medical School

Michael T. Seilo, Ph.D.

Professor of Audiology, Western Washington University

Bo Søndergaard, M.Sc. (Physics)

Senior Consultant, Danish Electronics Light and Acoustics (DELTA)

Technical Advisor

Mark Bastasch

Acoustical Engineer, CH2M HILL

Panel Member Biographies

W. David Colby, M.D.

W. David Colby M.Sc., M.D., FRCPC, is a fellow of the Royal College of Physicians and Surgeons of Canada in Medical Microbiology. Dr Colby is the Acting Medical Officer of Health in Chatham-Kent, Ontario and Associate Professor of Medicine, Microbiology/Immunology and Physiology/Pharmacology at the Schulich School of Medicine and Dentistry at the University of Western Ontario. He received his M.D. from the University of Toronto and completed his residency at University Hospital, London, Ontario. While still a resident he was given a faculty appointment and later was appointed Chief of Microbiology and Consultant in Infectious Diseases at University Hospital. Dr Colby lectures extensively on antimicrobial chemotherapy, resistance and fungal infections in addition to a busy clinical practice in Travel Medicine and is a Coroner for the province of Ontario. He has received numerous awards for his teaching. Dr. Colby has a number of articles in peer-reviewed journals and is the author of the textbook *Optimizing Antimicrobial Therapy: A Pharmacometric Approach*. He is a Past President of the Canadian Association of Medical Microbiologists. On the basis of his expertise in Public Health, Dr Colby was asked by his municipality to assess the health impacts of wind turbines. The report, titled *The Health Impact of Wind Turbines: A Review of the Current White, Grey, and Published Literature* is widely cited internationally.

Robert Dobie, M.D.

Robert Dobie, M.D., is clinical professor of otolaryngology at both the University of Texas Health Science Center at San Antonio and the University of California-Davis. He is also a partner in Dobie Associates, a consulting practice specializing in hearing and balance, hearing conservation, and ear disorders. The author of over 175 publications, his research interests include age-related and noise-induced hearing loss, as well as tinnitus and other inner ear disorders. He is past president of the Association for Research in Otolaryngology, past chair of the Hearing and Equilibrium Committee of the American Academy of Otolaryngology-Head and Neck Surgery, and has served on the boards and councils of many other professional organizations and scholarly journals.

Geoff Leventhall, Ph.D.

Geoff is a UK-based noise and vibration consultant who works internationally. His academic and professional qualifications include Ph.D. in Acoustics, Fellow of the UK Institute of Physics, Honorary Fellow of the UK institute of Acoustics (of which he is a former President), Distinguished International Member of the USA Institute of Noise Control Engineering, Member of the Acoustical Society of America.

He was formerly an academic, during which time he supervised 30 research students to completion of their doctoral studies in acoustics. Much of his academic and consultancy work has been on problems of infrasound and low frequency noise and control of low frequency noise by active attenuation

He has been a member of a number of National and International committees on noise and acoustics and was recently a member of two committees producing reports on effects of noise on health: the UK Health Protection Agency Committee on the Health Effects of

Ultrasound and Infrasound and the UK Department of Health Committee on the Effects of Environmental Noise on Health.

David M. Lipscomb, Ph.D.

Dr. David M. Lipscomb received a Ph. D. in Hearing Science from the University of Washington (Seattle) in 1966. Dr. Lipscomb taught at the University of Tennessee for more than two decades in the Department of Audiology and Speech Pathology. While he was on the faculty, Dr. Lipscomb developed and directed the department's Noise Research Laboratory. During his tenure at Tennessee and after he moved to the Pacific Northwest in 1988, Dr. Lipscomb has served as a consultant to many entities including communities, governmental agencies, industries, and legal organizations.

Dr. Lipscomb has qualified in courts of law as an expert in Audiology since 1966. Currently, he investigates incidents to determine whether an acoustical warning signal provided warning to individuals in harms way, and, if so, at how many seconds before an incident. With his background in clinical and research audiology, he undertakes the evaluation of hearing impairment claims for industrial settings and product liability.

Dr. Lipscomb was a bioacoustical consultant to the U. S. Environmental Protection Agency Office of Noise Abatement and Control (ONAC) at the time the agency was responding to Congressional mandates contained in the Noise Control Act of 1972. He was one of the original authors of the Criteria Document produced by ONAC, and he served as a reviewer for the ONAC document titled *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*. Dr. Lipscomb's experience in writing and reviewing bioacoustical documentation has been particularly useful in his review of materials for AWEA regarding wind farm noise concerns.

Robert J. McCunney, M.D.

Robert J. McCunney, M.D., M.P.H., M.S., is board certified by the American Board of Preventive Medicine as a specialist in occupational and environmental medicine. Dr. McCunney is a staff physician at Massachusetts General Hospital's pulmonary division, where he evaluates and treats occupational and environmental illnesses, including lung disorders ranging from asbestosis to asthma to mold related health concerns, among others. He is also a clinical faculty member of Harvard Medical School and a research scientist at the Massachusetts Institute of Technology Department of Biological Engineering, where he participates in epidemiological research pertaining to occupational and environmental health hazards.

Dr. McCunney received his B.S. in chemical engineering from Drexel University, his M.S. in environmental health from the University of Minnesota, his M.D. from the Thomas Jefferson University Medical School and his M.P.H. from the Harvard School of Public Health. He completed training in internal medicine at Northwestern University Medical Center in Chicago. Dr. McCunney is past president of the American College of Occupational and Environmental Medicine (ACOEM) and an accomplished author. He has edited numerous occupational and environmental medicine textbooks and over 80 published articles and book chapters. He is the Editor of all three editions of the text book, *A Practical Approach to Occupational and Environmental Medicine*, the most recent edition of which was published in 2003. Dr. McCunney received the Health Achievement Award from ACOEM in 2004.

Dr. McCunney has extensive experience in evaluating the effects of noise on hearing via reviewing audiometric tests. He has written book chapters on the topic and regularly lectures at the Harvard School of Public Health on "Noise and Health."

Michael T. Seilo, Ph.D.

Dr. Michael T. Seilo received his Ph.D. in Audiology from Ohio University in 1970. He is currently a professor of audiology in the Department of Communication Sciences and Disorders at Western Washington University in Bellingham, Washington where he served as department chair for a total of more than twenty years. Dr. Seilo is clinically certified by the American Speech-Language-Hearing Association (ASHA) in both audiology and speech-language pathology and is a long-time member of ASHA, the American Academy of Audiology, and the Washington Speech and Hearing Association.

For many years Dr. Seilo has taught courses in hearing conservation at both the graduate and undergraduate level. His special interest areas include speech perception and the impact of noise on human hearing sensitivity including tinnitus.

Dr. Seilo has consulted with industries on the prevention of NIHL and he has collaborated with other professionals in the assessment of hearing-loss related claims pertaining to noise.

Bo Søndergaard, M.Sc. (Physics)

Bo Søndergaard has more than 20 years of experience in consultancy in environmental noise measurements, predictions and assessment. The last 15 years with an emphasis on wind turbine noise. Mr. Søndergaard is the convenor of the MT11 work group under IEC TC88 working with revision of the measurement standard for wind turbines IEC 61400-11. He has also worked as project manager for the following research projects: Low Frequency Noise from Large Wind Turbines for the Danish Energy Authority, Noise and Energy optimization of Wind Farms, and Noise from Wind Turbines in Wake for Energinet.dk.

Technical Advisor Biography

Mark Bastasch

Mr. Bastasch is a registered acoustical engineer with CH2M HILL. Mr. Bastasch assisted AWEA and CanWEA in the establishment of the panel and provided technical assistance to the panel throughout the review process. Mr. Bastasch's acoustical experience includes preliminary siting studies, regulatory development and assessments, ambient noise measurements, industrial measurements for model development and compliance purposes, mitigation analysis, and modeling of industrial and transportation noise. His wind turbine experience includes some of the first major wind developments including the Stateline project, which when built in 2001 was the largest in the world. He also serves on the organizing committee of the biannual International Wind Turbine Noise Conference, first held in Berlin, Germany, in 2005.